EPE Online

www.epemag.com

Volume 2 Issue 4
April 2000

WARNING!

Contents

PROJECTS AND CIRCUITS

SERIES AND FEATURES

REGULARS AND SERVICES

Editorial

ODD REQUESTS

We get some odd requests via email at *EPE Online* and at the printed edition *EPE* (including the occasional rude comment (see Readout). In fact there seems to a lack of understanding about the relationship between *EPE* and *EPE Online* in some cases. The printed edition of *EPE* is based in the UK, and virtually all of the magazine's content is edited by the *EPE* Editorial Office in the UK. *EPE Online* and the *EPE Online* web site is run for by Clive (Max) Maxfield and Alvin Brown based in the USA.

The idea of *EPE Online* is that readers can purchase and download the magazine online from anywhere in the world, almost instantly. You log on to the **www.epemag.com** web site, punch in your credit card details to pay for an issue $5 (US) or a year's subscription at $9.99 (US) and then you can download the magazine from that web site to your computer, read it on screen, or print it out as required. It is not sent to you via email, but you will get an email telling you when each issue is available (usually just after the printed issue is on sale in UK shops) so you can then log on and download the magazine.

We charge for *EPE Online* in US dollars, but that charge will be automatically converted to your local currency by your credit card provider. If you pay from the UK, for example, a 12-month subscription to the online edition will cost about 6.25 UK Pounds, depending on the pound/dollar exchange rate at the time.

The online edition presently carries no advertising from component suppliers etc., but we are in the process of changing that and no doubt some printed issue advertisers will take up online advertising in the coming months. Incidentally, the *EPE Online* web site presently receives about 22,000 hits a week.

EDITORIAL QUERIES

Because the editorial material for *EPE Online* is produced by the editorial office in the UK, technical queries on projects etc. should be directed to **techdept@epemag.wimborne.co.uk** and not to the online offices in the USA (who will only forward them to the UK for reply).

We are not able to supply material – either individual articles or whole issues – by email. If you require material on an "instant" basis then you can buy back issues and download them from the *EPE Online* web site. Alternatively, you can order printed back issues from the UK web site, these are then posted out, usually within five working days. The *EPE Online* web site carries material from the November 1998 issue onwards so you cannot obtain earlier articles by download via the web, you will then have to order printed back issues.

We hope this makes everything clearer (as clear as mud some might say), if not please let us know.

Clive Maxfield & Alvin Brown

Next Month

VERSATILE MICROPHONE/AUDIO PREAMPLIFIER

One of the latest chips on the block, the Analog Device SSM2166P, is a low noise, low distortion, dynamic range compressor with a number of interesting features. In this design it provides a very versatile preamplifier with automatic gain control, signal limiting, variable compression and noise reduction circuitry. The design is suitable for a wide range of applications from PA and surveillance systems to amateur radio and audio. Additional circuitry is given for readers who require a signal strength meter.

SIXTEEN-CHANNEL TWO-WIRE TRANSMISSION SYSTEM

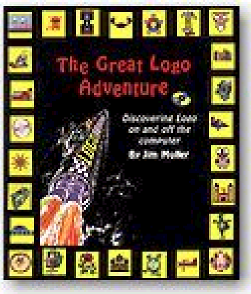
The uses for this PIC-based project are limited only by the ingenuity of the constructor. Everything from extra inputs for simple security projects to communications, signaling and control of complex systems over long distances can be handled, and the modules described may be tailored to give only the degree of sophistication required for minimum cost.

The units can be configured to provide either eight or sixteen channels, and where eight are used the system may be upgraded later by simply plugging in extra PICs, It will operate in both directions or just one, and with one-way operation the transmitter may be powered from the receiver through the signaling circuit, making it easy to monitor up to sixteen remote inputs through just a two-cor

e connecting lead. There is an optional interface for use with low-amplitude audio circuits which can be omitted where direct cable connection is possible. These options should allow this to find many uses in signaling, security and remote control projects.

Go to next section

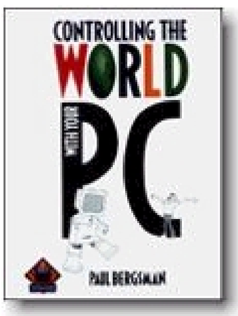
A selection of ELECTRONIC Books



The Great Logo Adventure

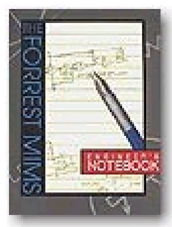
A cartoon-illustrated, family activity book for exploring animation, graphics, math, geometry, ... Ideal for teaching programming concepts to young people of all ages.
FREE CD-ROM (for PCs and Macs) contains Logo software plus lots of other stuff.

More details are available on the EPE Online web site



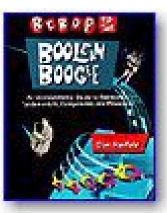
Controlling the World With Your PC

Connect your MS-DOS/Windows PC to the real world with this best-selling book!
Comes with all software (executable files plus C, Basic, and Pascal



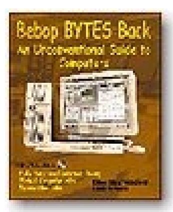
Forrest Mims Engineer's Notebook

This revised edition includes hundreds of useful circuits designed and built by Forrest using commonly available integrated circuits and other components.



Bebop to the Boolean Boogie (An Unconventional Guide to Electronics)

This in-depth, highly readable, up to the minute guide shows you how electronic devices work and how they're made -- the only electronics book where you can learn about musical socks and the best time of the day to eat smoked fish!

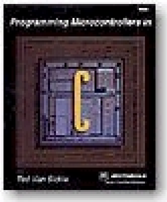


Bebop BYTES Back (An Unconventional Guide to Computers)

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work.
FREE CD ROM contains the *Beboputer Computer Simulator*, along with over 200 megabytes of mega-cool multimedia.

Visit the EPE Online Store at
www.epemag.com and place your order today!

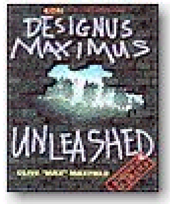
A selection of ELECTRONIC Books



Programming Microcontrollers in C

More Info or Buy Now!

This book opens with a quick review of the essentials of C programming and then examines in depth the issues faced when writing C code for microcontrollers.



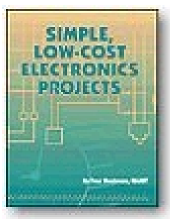
Designus Maximus Unleashed

(Banned in Alabama)

This unabridged and unexpurgated tome contains the definitive collection of Clive "Max" Maxfield's wildly popular articles published in leading electronics magazines. FREE CD-ROM contains a logic synthesis tool, a digital logic design system, & ...

3D Graphics Supercomputing on Windows NT

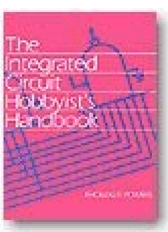
Explains the concepts behind 2D and 3D computer graphics. In addition to easy to understand text, the book is packed with superb color graphics that fully illustrate the points behind each topic. **($9.99 Special Offer! -- While Stocks Last!)**



Simple, Low-Cost Electronics Projects

More Info or Buy Now!

Whether you're a beginner to electronics or an old hand, don't miss this new book of do-it-yourself electronics projects.



Integrated Circuit Hobbyist Handbook

More Info or Buy Now!

Work with CMOS or TTL digital ICs? Use op amps and other linear devices? Need an application circuit using popular, readily available ICs? Then this handy reference is a "must have"!

More details are available on the EPE Online web site

Visit the EPE Online Store at

www.epemag.com and place your order today!

FLASH SLAVE

by ROBERT PENFOLD

Create the right image with this low-cost photographic aid.

Cameras have undoubtedly increased in sophistication over the last ten years or so, with features such as auto-focus and built-in flashguns now being commonplace. On the other hand, a few "standard" features seem to have become rarities that are featured on little more than a few up-market cameras.

The humble flash socket certainly falls into this category. At one time even the cheapest of compact cameras had this feature, but it seems to have disappeared in favor of an integral flashgun. It is actually quite a rarity on modern SLR cameras, although most sport a "hot shoe" that can be connected to a standard flash lead via an adapter. Most digital cameras seem to be styled on 35 millimeter and APS compact cameras, and have a built-in flashgun and no flash socket.

SECONDS OUT

For most users this lack of an external flash connector is probably of little consequence, but it is a major drawback for anyone wishing to go beyond simple "point and shoot" flash photography. The problem with a single flashgun is that it tends to produce a single shadow that is very strong and over-obvious. A balance of flash light and natural light generally gives better results, but is only possible if there is sufficient natural light and the camera can handle this type of lighting.

A more practical solution is to use a second flashgun, well separated from the main flashgun, to provide some fill-in lighting. Ideally the second gun should be a type that has variable output power so that the fill-in light can be balanced properly with the main light. However, even the cheapest of flashguns is good enough to provide a bit of fill-in lighting.

If a camera lacks a flash socket but does have a built-in flashgun, it is actually possible to use a second gun. In fact several additional guns can be used, but with more flashguns it obviously becomes more difficult to get the required lighting effect and the correct exposure. In order to fire the secondary guns it is merely necessary to have each one triggered via a slave unit. A flash slave is just a high-speed light activated switch that triggers a secondary flashgun

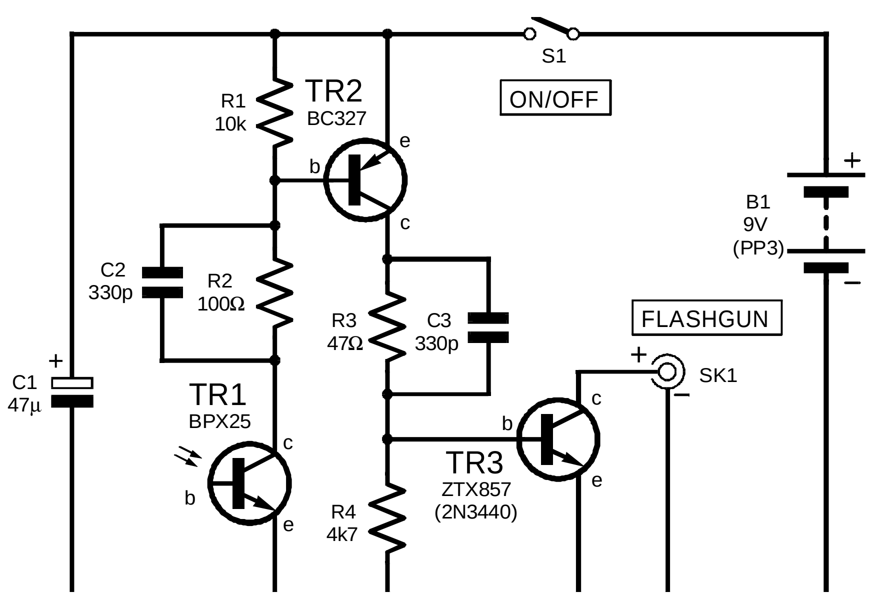


Fig.1. Complete circuit diagram for the Flash Slave.

Finished unit showing the "light window" and extension lead socket.

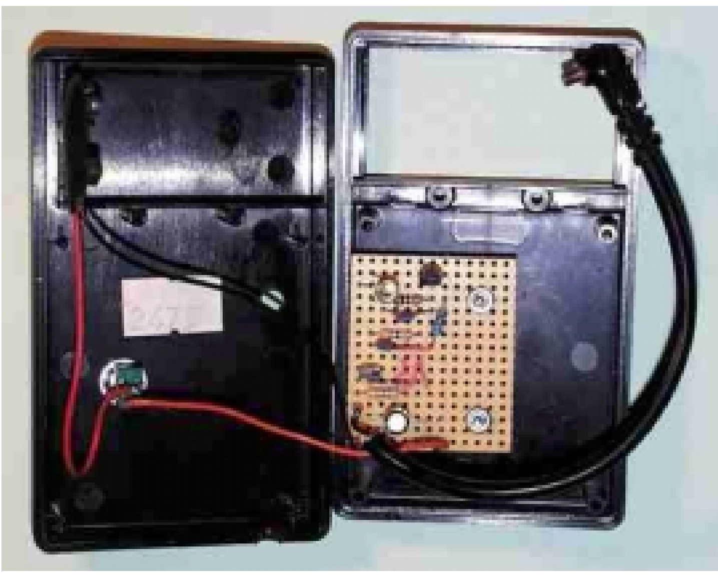
when it detects the flash of light from the main gun.

Provided the camera has a built-in flash unit, flash slaves enable any number of extra flashguns to be used without the need for any form of external flash connections on the camera. Even if you use a camera that has a standard flash socket, it can still be advantageous to use flash slave units.

Multi-flash photography using connecting cables is slightly risky because there are inevitably long trailing cables that are easily tripped over. Apart from the personal safety aspect, with such a set up it is very easy to do a lot of expensive damage to the equipment.

CIRCUIT OPERATION

The full circuit diagram for the Flash Slave appears in Fig.1. For many years flash slave units used a triac or a thyristor as the switching device



The two halves of the completed Flash Slave case showing positioning of the circuit board and mounting of the On/Off switch.

at the output. A device of either type was a good choice in the days when flashguns had high voltage trigger circuits that operated at around 150V to 180V.

An inexpensive thyristor or triac could handle the high voltages, and the switching action provided by one of these devices was all that was needed in this application. Unfortunately, most modern flashguns operate with much lower trigger voltages of around 12V to 24V, and the voltage drop through a triac or thyristor can prevent them from triggering these flashguns reliably.

Another common problem is that of the flash being triggered correctly the first time, but not firing on subsequent attempts. The unit can be made to work again by switching it off, waiting a few seconds, and then turning it back on. However, the flash only triggers once and then refuses to co-operate again!

The significant current that flows once the flash has been triggered causes this odd behavior. Unlike a transistor, a triac or thyristor remains switched on until the current flow falls to a low level.

With older flashguns there is a high current flow during triggering, followed by a negligible current flow thereafter, causing the device to switch off. With low voltage trigger circuits the current flow is high enough to hold the triac or thyristor switched on. This usually stops the gun from operating, rather than causing it to fire each time an adequate charge is reached.

TRANSISTOR

COMPONENTS

Resistors
- R1 10k
- R2 100 ohms
- R3 47 ohms
- R4 4k7

All 0.25W 5% carbon film

Capacitors
- C1 47u radial electrolytic, 25V
- C2, C3 330p ceramic plate (2 off)

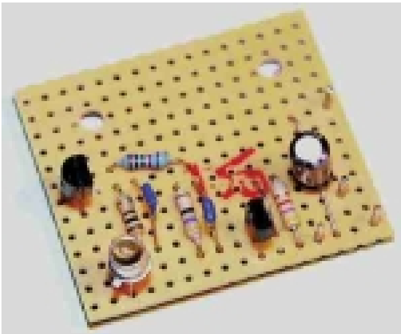
Semiconductors
- TR1 BPX25 silicon *npn* phototransistor (see text)
- TR2 BC327 *pnp* medium power transistor
- TR3 ZTX857 (or 2N3440) *npn* high-voltage transistor

Miscellaneous
- SK1 flash pocket (see text)
- B1 9V (PP3 size) battery
- S1 s.p.s.t. miniature toggle switch

Small plastic case, approximately 100mm x 60mm x 23mm; 0.1-inch stripboard, 16holes by 13 strips; battery connector; multistrand connecting wire, solder pins; solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only (Excluding Batts) **$22**



SWITCHING

Modern flash slave units use an ordinary transistor as the switching element. When driven with a suitably strong base (b) current a transistor will reliably trigger virtually any flashgun, ancient or modern. Once the pulse of light from the main gun has ceased, the base current to the transistor ends and the device switches off. This ensures that the flashgun can recycle properly, even if it is a type that has a low voltage trigger circuit.

Of course, the transistor must be a high voltage type if the slave unit is to be used to trigger a flashgun that has a high voltage trigger circuit. The switching transistor in this circuit is TR3, and the specified component has a collector-to-emitter voltage rating of 300V, which is comfortably higher than the maximum voltage it is likely to receive. It also has a high peak collector (c) current rating of 5A, which is substantially higher than its likely operating current in this application.

Other transistors having a similarly high voltage and current ratings should work equally well in this design, such as the 2N3440 (which has a TO39 encapsulation and not an E-Line type). Lower voltage types should only be used if the unit will be used exclusively to control guns having low voltage trigger circuits.

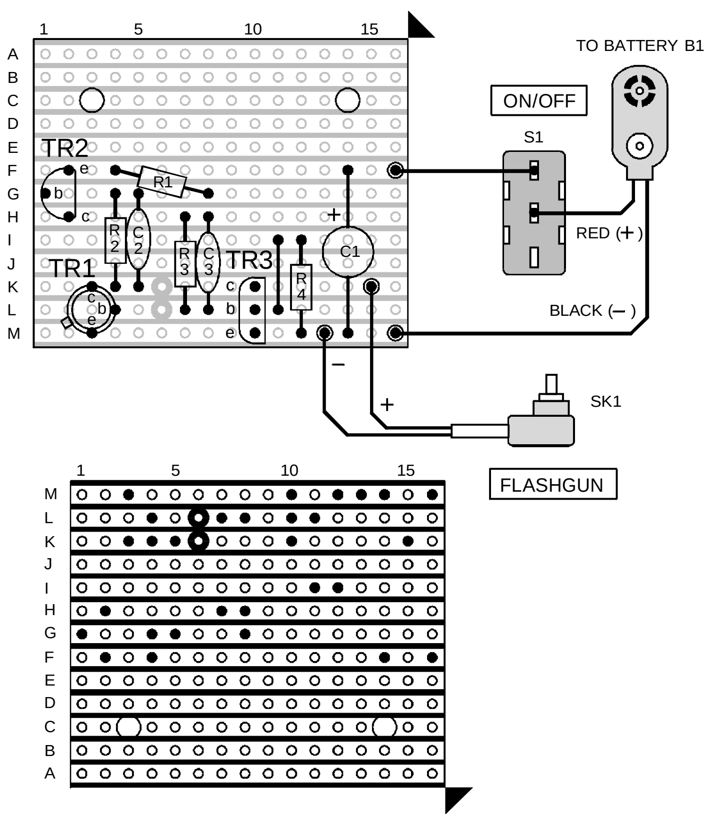


Fig.2. Flash Slave component layout and interwiring.

RESPONSE TIME

It is important that the slave unit has a very short response time. If there is fast subject movement, a gap of even a few milliseconds between the two flashes could produce a noticeable double-image effect. Another problem is that of the shutter closing before the second flash has a chance to fire.

This is not a problem if the camera gives a degree of manual control, since the user can set a shutter speed that is long enough to embrace the second flash. It is a potential problem if the camera automatically sets the minimum acceptable shutter speed for flash operation when the built-in flash unit is used. With the leaf shutters used in most compact cameras the highest shutter speed for flash can be less than two-milliseconds (1/500th second).

In order to ensure that the slave reacts quickly enough it is important to use a fast photocell, and in practice this means using either a phototransistor or a photodiode. Cadmium sulphide photo-resistors and photo-Darlington devices are not fast enough.

A phototransistor (TR1) is used in this design, but a photodiode can be used if preferred. Under dark conditions a phototransistor operates much like any other transistor, and with no base current applied only minute leakage currents flow in the collector-emitter circuit.

When a phototransistor is subject to light the leakage currents become much larger. The higher the light level the greater the leakage current that

flows. Under standby conditions the leakage current through phototransistor TR1 is inadequate to bias the *pnp* transistor TR2 into conduction, but TR2 is switched on during the brief pulse of current from the primary flashgun. It in turn supplies a strong base current to transistor TR3, which conducts heavily and triggers the secondary flashgun. Note that the flashgun must be connected to TR3 with the polarity shown in Fig.1 in order to obtain reliable triggering.

Resistors R2 and R3 respectively limit the collector currents of TR1 and TR2 to safe levels, and capacitors C2 and C3 slightly improve the response time of the circuit. A BPX25 is specified for TR1, but on trying several silicon npn phototransistor in the circuit they all provided satisfactory results.

For the fastest response time a photo-diode should be used in place of TR1. Connect the anode (a) and cathode (k) terminals in place of TR1's emitter (e) and collector (c) respectively.

The sensitivity of a photodiode is much less than that of a phototransistor, but omitting resistor R1 will largely compensate for this. Any general-purpose photodiode should be suitable, but infrared types do not seem to work well in this application.

The current consumption of the circuit under standby conditions is only the leakage current through phototransistor TR1, which is normally less than 50mA. A PP3 size battery is therefore adequate to power the unit, and should provide more than 1000 hours of operation.

CONSTRUCTION

The Flash Slave circuit is built up on a small piece of stripboard having 16 holes by 13 copper strips. The topside component layout, together with the underside details, is shown in Fig.2. Only two breaks in the copper strips are needed.

Unless you have a suitable off-cut, commence construction by cutting a standard piece of stripboard down to size using a hacksaw and then drilling the two 3·3mm dia. mounting holes. These will accept either 6BA or metric M3 mounting bolts.

Plastic stand-offs are not a good choice for use with stripboard because most types do not provide a secure mounting when used with this type of board. The two breaks in the strips can be made using the special tool, or a twist drill bit of about 5mm in diameter will do the job well.

Although there are few components to deal with, there is not much space for them on the circuit board. Everything should still fit into place without too much difficulty provided miniature components are used. In particular, C2 and C3 must be ceramic plate capacitors or some other miniature ceramic type. It is unlikely that other types such as polystyrene capacitors will fit successfully into this layout.

Transistor TR3, used in the prototype, has an unusual encapsulation know as an E-Line case. At first glance it looks symmetrical, but if you look at it closely it becomes apparent that one side is flat and the other has slightly rounded corners. The type number is on the side that has the rounded corners, and this side faces towards capacitor C3, see Fig.2 and photographs. Fit solder pins to the board at the points where connections will be made to the in-line socket SK1, switch S1, and the battery.

CASING UP

Virtually any small plastic box should be adequate to accommodate this small project. The prototype is housed in a case that measures about 100mm x 60mm x 23mm, and this is slightly larger than the bare minimum.

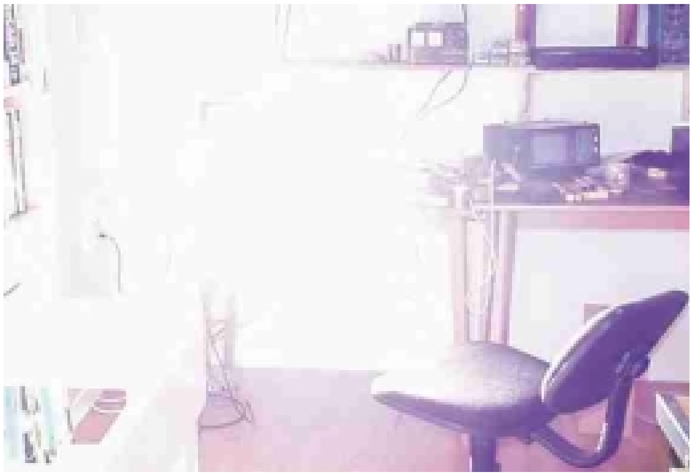
The circuit board is mounted on the rear panel of the case, well towards one end so that there is sufficient space for the battery at the other end. On/Off switch S1 is mounted at any convenient position on the front panel.

A "window" for photocell TR1 is needed in the front panel, and there are two ways of tackling this. The method used on the prototype is to drill a hole of about 5mm diameter in the front panel, directly in front of TR1. With the leads of TR1 left quite long this brings it into the hole when the two halves of the case are fitted together.

The alternative, and slightly easier method, is to crop the leads of TR1 quite short, and to make a much larger "window" in the front panel. Some clear plastic should be glued over the rear of the "window" to keep dust out of the case.

FLASH CONNECTOR

The miniature coaxial connectors used for flashguns seem to be impossible to obtain these days, but flash extension leads can be obtained from photographic shops at reasonable prices. Cut the socket from the extension lead,



Test shot result showing "light burst" produced by pointing the "master" directly at the "slave".

together with about 150mm to 250mm of cable. Incidentally, the in-line version of the socket fitted to flash extension leads is actually the one that looks like a plug.

Drill a hole of about 4mm diameter in the case for the lead, thread it through the hole, prepare the end of the cable, and then connect the two wires to the circuit board. The unit will not work properly unless the flash lead is connected with the polarity indicated in Fig.2.

Ideally a voltmeter should be used to check the polarity of the potential on this lead, but trial and error can be used if necessary. It is very unlikely that connecting the flash lead with the wrong polarity will damage anything. Most flash leads have black and white insulation on the leads, and the black lead is usually the negative (–) lead.

To complete the unit, connect the black (–) battery clip lead and the lead from switch S1 to the circuit board. The red (+) lead from the battery clip goes to the switch, see Fig.2. After a final check through the unit is now ready for testing.

IN USE

When initially testing the unit it is best to try it at almost point blank range. If all is well try it at longer ranges, but switch off immediately and recheck the wiring if it fails to trigger the flashgun properly. Avoid aiming photocell TR1 towards strong light sources as this could result in the unit being held in the triggered state. This will prevent it from working and will greatly reduce the life of the battery.

The maximum range depends on the power of the primary flashgun and the precise characteristics of the photocell used for TR1, but it should be several meters or more. Raising the value of resistor R1 will increase the sensitivity of the unit, but this also increases the possibility of a strong ambient light level holding the unit in the triggered state.

When used indoors it is not normally necessary to aim the photocell at the primary flashgun, because light reflected from the walls, ceiling, etc. is usually sufficient to trigger the unit. When used in a large building or out of doors there will be less reflected light and it will then be necessary to aim it at the master flash unit in order to obtain reliable triggering.

The easy way of handling this is to fix the slave on one side of the secondary flashgun or on a separate lighting stand using something like Bostik Blu-Tack. The Blu-Tack provides a sort of universal joint that makes it easy to aim the flashgun in practically any desired direction.

Bear in mind that the light from the secondary flashgun will increase the exposure slightly. Provided the light from the secondary gun is relatively weak it will not alter the exposure sufficiently to give any major problems, even when using transparency film. The exposure latitude of print films is such that even an extra stop or so of exposure from the secondary flashgun should still achieve good results.

If you wish to check that the unit is responding quickly enough, the only sure test is to take some test shots. If you take a photograph of the slave flashgun and it comes out properly, the slave is not acting quickly enough and a longer shutter speed must be used. If you get what looks like a photograph of an explosion (below), the slave flashgun is being triggered fast enough.

Constructional Project

GARAGE LINK

by TERRY de VAUX_BALBIRNIE

Have you left the garage door open all night again? You need this versatile, license exempt, coded radio link.

Have you ever gone to get the car out of the garage and found that you left the door open all night? With luck, the car is still there and everything inside the garage untouched. You breath a sigh of relief and vow to be more careful in future.

OPEN DOOR

But what if the car had been stolen? How would you square that with the insurance company when you declared that the car is left overnight "in a secure garage"? What about the expensive power tools, bicycles, and gardening equipment you keep there?

These would be easily removed by any opportunist prowler. You could hardly show the "forcible entry" needed to make a claim on your household policy when all he had to do was walk in and take what he wanted!

WIRELESS LINK

This *Garage Link* circuit helps to prevent the garage door (or either door in the case of a double garage having twin doors) being left open all night. It works by establishing a radio link between the garage transmitter and some point inside the house. The indoor receiver then provides an audible warning in the form of a short bleep every 45 seconds.

The likely operating range is difficult to predict. In the open air, the prototype operated reliably at a distance of over 20 meters (66ft). However, the range will be much less when used in buildings. The presence of metallic objects and even ordinary building materials will reduce the signal.

The prototype units were set up under "fair" conditions. The garage was built with single brick walls and the house with double walls made of brick and breeze block. The easily-obtainable range was approximately 8 to 10 meters (26ft to 33ft). Obviously working to as short a range as practicable will give the most reliable results.

ON SITE

With the likely operating distance in mind and before beginning construction work, it is essential to check that there are suitable positions for the two units. The garage Transmitter does not need to be particularly close to the door as long as a piece of twin wire can be connected to it from a "remote" trigger switch there. It is better, in fact, if it is kept away from the door if this is made of metal.

Both units should be sited clear of large metallic objects. There should be a mains socket near the house-based Receiver because it is operated using a plug-in power supply unit.

The garage section is battery-operated, using a pack of four "AA" size cells inside the case. This avoids the need for a mains supply in the garage with possible safety implications. The batteries should last for one year approximately.

Of course, applications for this circuit are not confined to monitoring garage doors and many readers will have their

Self-contained Transmitter.

own ideas about how to use it. Because the Transmitter is self-contained, it could be used to monitor other doors, gates, windows, etc. In some situations, it would be necessary to use a waterproof enclosure but this is left up to the constructor.

LIGHT WORK

Since people often wish to leave the garage door open during the day, operation is held off until the light falls to a certain preset level. Another point is that the door might have been left open in the evening on purpose – perhaps because a member of the family is expected home soon.

This is one reason why the warning is given intermittently. It may then be ignored if required. The other reason is that it saves battery power.

Designing a circuit which would sound a warning if the garage door was left open would be easy if there was a clear path for a length of wire to

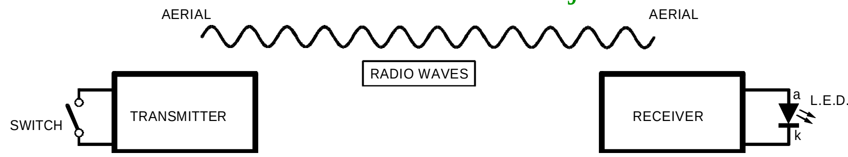


Fig.1. Block schematic of a simple radio link.

be laid between a switch at the door and a unit inside the house. Unfortunately, this is not usually the case.

Even where it would be theoretically possible to run such a wire, it is unlikely that there would be a neat and simple way of doing it. It would also involve drilling holes through walls or window frames. This is why it was decided to use a different approach and base this system on a radio link.

FOLLOW THE BAND

The use of the radio frequency (RF) spectrum is carefully controlled with specific bands being allocated for various purposes. In the UK, the body that oversees this is the Department of Trade and Industry (DTI). Some frequency bands are reserved for radio

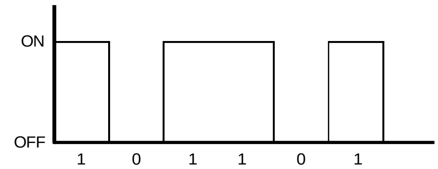


Fig.2. Transmitter code.

and TV broadcasting, some for military, some for radio amateurs, some for the public services and so on.

Some small bands of frequencies are left on a license-exempt basis and may be used by anyone. However, strict regulations exist for their use. In particular, the power radiated must be extremely small so that no appreciable signal may be detected more than a short distance from the transmitter.

One such frequency is 418MHz and this is used for certain local pagers, car security devices, "wireless" house alarms

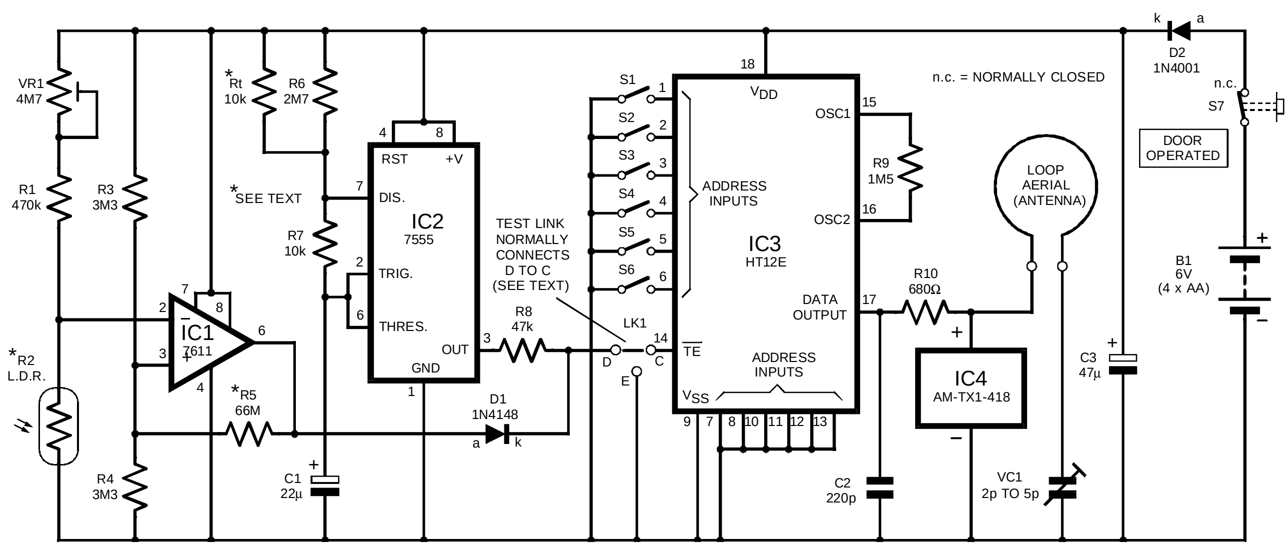


Fig.3. Circuit diagram for the Transmitter section of the Garage Link. Note that the normally closed contacts of microswitch S7 are used and that closing the garage door opens them. The "TE" designation at IC3 pin 14 means Transmit Enable (the bar over it means this signal's active state is

and so on. However, due to so-called TETRA services operating at around this frequency and more so in the future, the DTI have licensed 433MHz for the same purpose.

This frequency is already in widespread use in mainland Europe. Note that these are actually narrow bands (that is, ranges) of frequencies but for the sake of simplicity they are stated as spot values – 418MHz and 433MHz.

NO GUARANTEES

Although 433MHz equipment is probably less likely to suffer from interference problems especially in the coming years, there is always some risk of this occurring whichever frequency is used. Correct operation therefore cannot be guaranteed under all circumstances.

The prototype unit operates at 418MHz because the necessary modules were readily available at the time. However, there is no reason why similar 433MHz modules could not be used.

Another choice is whether to use AM (amplitude modulation) or FM (frequency modulation). Frequency modulation is more immune from interference, would provide a greater range and, for critical applications, would probably be better. However, here the less sophisticated AM system was used and it performed perfectly well.

For those who are interested, modulation is the way in which radio waves carry data. With AM it is the signal strength (amplitude of the waves) emitted by the transmitter which is varied with the frequency remaining constant. In the simplest case, this is performed by switching it on and off. With FM it is the frequency of the waves which is shifted slightly while keeping a constant amplitude.

COMMERCIAL MODULES

To allow the use of home-made transmitters would lead the way to potentially botched equipment causing interference

COMPONENTS

TRANSMITTER

Resistors
- R1 470k
- R2 sub-miniature light dependent resistor (LDR) -- dark resistance approximately 5 megohm (see text)
- R3, R4 3M3 (2 off)
- R5 66M (2 x 33M connected in series -- see text)
- R6 2M7
- R7 10k
- R8 47k
- R9 1M5 (or 1M and 470k in series -- see text)
- R10 680 ohms
- Rt 10k (test -- see text)

All 0.25W 5% carbon film, except R2

Potentiometer
- VR1 4M7 miniature preset, horizontal

Capacitors
- C1 22u radial electrolytic, 10V
- C2 220p polystyrene
- C3 47u radial electrolytic, 10V
- VC1 miniature preset trimmer 2pF to 5pF

Semiconductors
- D1 1N4148 signal diode
- D2 1N4001 1A 50V rectifier diode
- IC1 ICL7611 micropower opamp
- IC2 ICM7555IPA CMOS timer
- IC3 HT12E encoder
- IC4 AM-TX1-418 transmitter module (see text)

Miscellaneous
- S1 to S6 DIP switches (one strip of six)
- S7 lever-arm microswitch
- B1 6V battery pack (4 x AA)

PCB available from the *EPE Online Store* (code 7000261 -- transmitter) at **www.epemag.com**; plastic case size 118mm x 98mm x 45mm; 8-pin DIL IC socket (2 off); 18-pin DIL IC socket; battery connector (PP3 type); bracket for microswitch -- see text; connecting wire, solder, etc.

RECEIVER

Resistors
- R1 100k
- R2 10k

Both 0.25W 5% carbon film

Capacitors
- C1, C2 470n miniature metallized polyester -- 2.5mm pin spacing (2 off)
- C3, C4 220n miniature metallized polyester -- 2.5mm pin spacing (2 off)
- C5 100u radial electrolytic, 25V

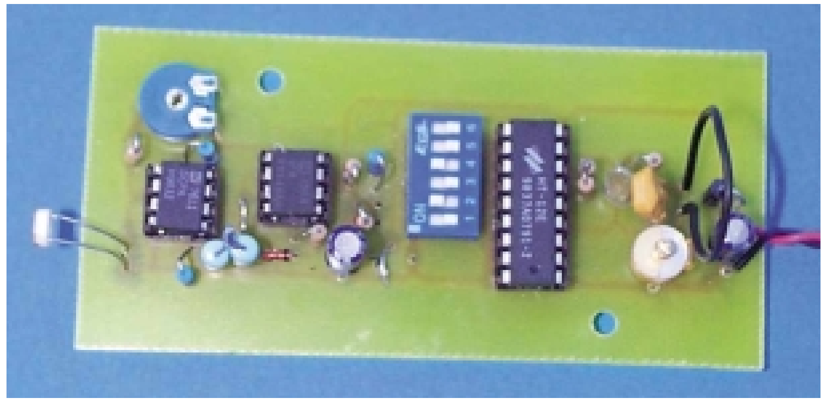
Semiconductors
- D1 1N4001 1A 50V rectifier diode
- TR1 ZTX300 *npn* general-purpose transistor
- IC1 AM-HRR3-418 receiver module
- IC2 HT12F decoder
- IC3 78L05 5V 100mA voltage regulator

Miscellaneous
- S1 to S6 DIP switches (one strip of six)
- WD1 piezo buzzer -- DC operation 3V to 24V at 10mA
- FS1 250mA miniature PCB mounting fuse (see text)

Printed circuit board available from the *EPE Online Store* (code 7000262 -- receiver) at **www.epemag.com**; plastic case size 102mm x 76mm x 38mm; 9V 300mA (unregulated) mains adapter plus socket to suit; 18-pin DIL IC socket; SIL socket for receiver module, see text; connecting wire, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only — *Transmitter (Excl. batts)* **$27** — *Receiver (Excl. mains adapter)* **$37**



with vital services. The actual transmitter (but not the circuit controlling it) must therefore be commercially-built to the prescribed specification. It is then said to be "DTI MPT1340 approved, W.T. license exempt".

Appropriate commercial modular transmitters are available quite cheaply. The simplest variety has only two wires, which are used for the power supply and aerial (antenna), and this is the type used in this project.

The receiver section is based on a matching receiver module. No traditional "radio" skills are therefore needed during construction and setting-up.

BASIC LINK

A simple radio link between two positions using a transmitter and receiver tuned to the same frequency is shown in Fig.1. Switching on ("keying") the transmitter would send out radio waves from its aerial. The signal would be picked up by an aerial at the receiver and, after suitable processing, the LED (light-emitting diode) connected to its output would operate. By switching the transmitter on and off, the LED would flash in sympathy.

However, this type of system would be vulnerable to false triggering. Every time the receiver picked up a signal from any other source of radio waves operating at or about the same frequency, the LED would come on.

To avoid this, the transmitter is keyed according to a certain pre-arranged digital code. Only if this code is matched at the receiver end will an output be given. The receiver may well pick up signals which carry no code at all or carry the wrong code (from similar equipment) but, in either case, it will have no effect.

CODED LINK

To illustrate this, suppose the code consists of the six-bit word: 1 0 1 1 0 1. In this case a "1" would be given by switching the transmitter on for a certain time and a "0" by switching it off for the same time. The signal given by the transmitter is shown graphically in Fig.2. The receiver would then be pre-set to "see" this code and no other.

In the *Garage Link*, the code has twelve bits (although only six of them may be changed by the user). It is, therefore, very unlikely that any signal, apart from the intended one, would carry the correct code. If someone within range happened to be operating similar equipment and using the same code then all that would be necessary would be to change it.

Unfortunately, any strong signal at about the working frequency and not carrying the code could swamp the receiver so that it would not "see" the weaker signal from the transmitter. During that time, no output would be given.

CIRCUIT DETAILS – TRANSMITTER

The complete circuit diagram of the Transmitter section of the *Garage Link* is shown in Fig.3. While the garage door is open, it allows the normally-closed (NC) contacts of microswitch S7 to close and establish a supply to the circuit from the 6V battery pack, B1. When the door is closed, the switch contacts open and no current flows. This method has the advantage that for much of the time, the battery is not being drained.

Diode D2 prevents damage to the circuit if the supply were to be connected in the wrong sense. If it was, the diode would not conduct and nothing would happen. For the moment, ignore IC1 and IC2. IC3 is an encoder,

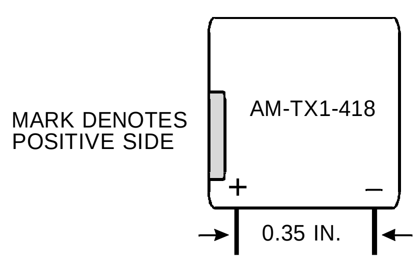
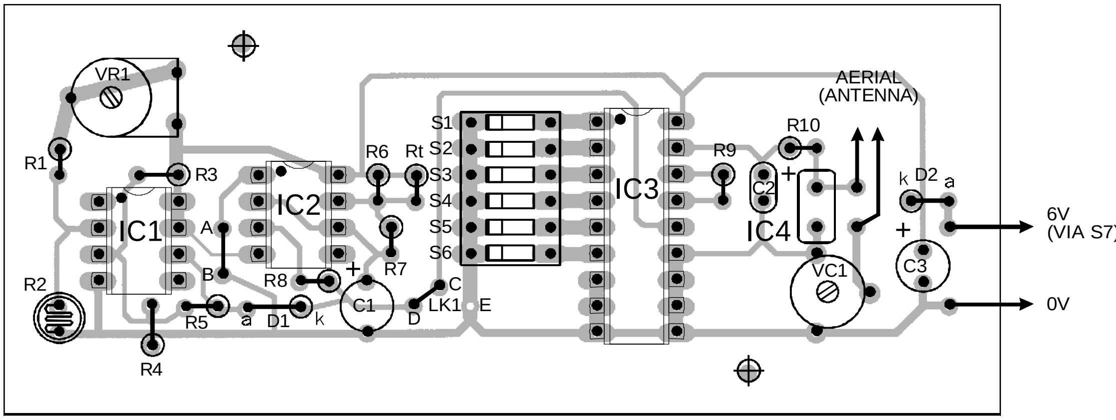


Fig.5. Transmitter module (IC4) pin polarity identification.



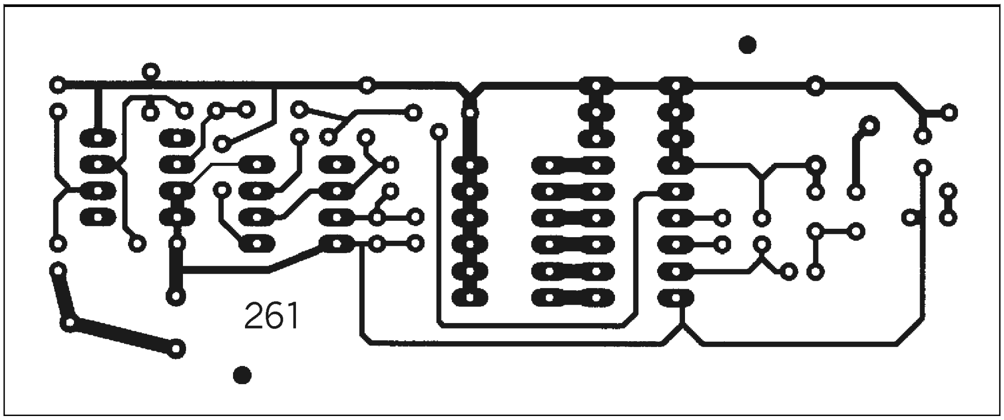


Fig.4. Printed circuit board component layout and (approximately) full size underside copper foil master for the transmitter.

which keys the transmitter according to the pre-arranged code. IC4 is the transmitter module.

The twelve address inputs of IC3 are at pins 1 to 8 and pins 10 to 13. These may be set to logical 1 or 0 to provide the chosen code. Four of the addresses could also be used to carry separate data but this is not done here.

To establish the code some of the address pins are connected to the 0V line to provide logical 0 status. Any pin left unconnected automatically assumes logic 1.

CODESETTING

Setting up the code is carried out using a set of DIP (dual in-line package) switches (S1 to S6) on the PCB (printed circuit board). With a switch on, a "0" is set and by switching it off, a "1". This gives a simple means of changing the code at any time if required.

It seemed unnecessary to allow user selection of all the addresses, so here only IC3 pin 1 to pin 6 may be set using the DIP switches. The other addresses (pins 7, 8 and 10 to 13) are tied to 0V together with pin 9 which is the 0V input, making them always logic "0".

When the TE (transmit enable) pin 14 is made low (imagine this is so for the moment), the data present on the address pins is given serially at the data output, pin 17. This is in the form of four-word groups and continues as long as pin 14 (TE) is kept low.

If it is low for less than the time taken for one word, it will still transmit a four-word group. When the low state of pin 14 is removed, pin 17 finishes its current cycle then stops.

The rate at which data is transferred is determined by the frequency of an on-chip oscillator. This, in turn, is set by the value of resistor R9 connected between pin 15 and pin 16 (Osc1 and Osc2). The specified value sets a frequency of 2kHz approximately.

The data from IC3 pin 17 is used to power the transmitter module direct. When it is high, the transmitter (IC4) receives current and sends out a signal. When low, it is off. A short loop aerial (antenna) is used to radiate the waves and trimmer capacitor VC1 is used to tune it for maximum signal strength.

PULSETIME

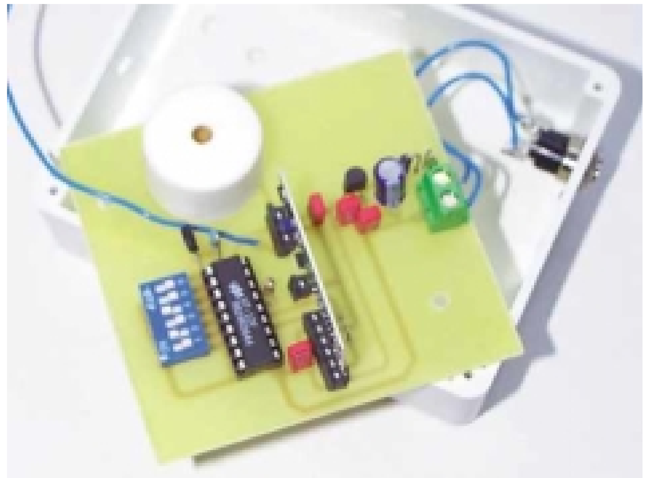
It is not necessary for the

Transmitter to be providing data continuously – in fact, this would run down the batteries without good reason. IC3 pin 14 (transmit enable) only needs to be pulsed low for sufficient time to provide the bleeps at the Receiver.

To provide these pulses, IC3 pin 14 is connected via resistor R8 and test link LK1, to the output (pin 3) of the astable based on timer IC2. A continuous string of pulses is then produced.

The frequency and mark/space ratio (that is, how long each pulse is high compared with low) is determined by the values of resistors R6 and R7 in conjunction with capacitor C1. With the values specified, one cycle is produced every 42 seconds with each "low" taking 0·2s but this is subject to a fairly wide tolerance.

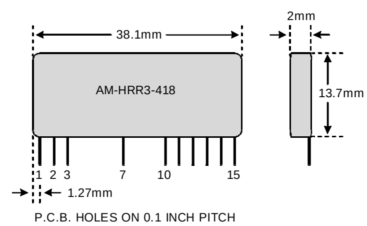
Test resistor *Rt* is connected in parallel with resistor R6 to begin with. This sets a much shorter time period (about half a second) so the buzzer bleeps rapidly. This will be useful for testing and setting-up purposes. At the end of setting up one of *Rt* end leads is cut to disconnect it from the circuit.



SEEING THE LIGHT

The light-sensing aspect of the circuit is based on operational amplifier (opamp) IC1. This inhibits the action of the encoder when the light level is high enough. The opamp is of a type which requires very little quiescent current (10uA approx.). It therefore has negligible effect on the life of the batteries.

The non-inverting input (pin 3) of IC1 receives a voltage equal to one-half that of the supply (nominally 3V) due to the potential divider action of resistors R3 and R4. The inverting input (pin 2) is connected to a further potential



PIN NO.	FUNCTION
1	R.F. V_{CC}
2	R.F. GND
3	ANTENNA
4,5,6	NOT CONNECTED
7	R.F. GND
8,9	NOT CONNECTED
10	A.F. V_{CC}
11	A.F. GND
12	A.F. V_{CC}
13	*TEST POINT
14	DATA OUTPUT
15	A.F. V_{CC}

*NOT USED

Fig.7. Receiver module pin layout and function details.

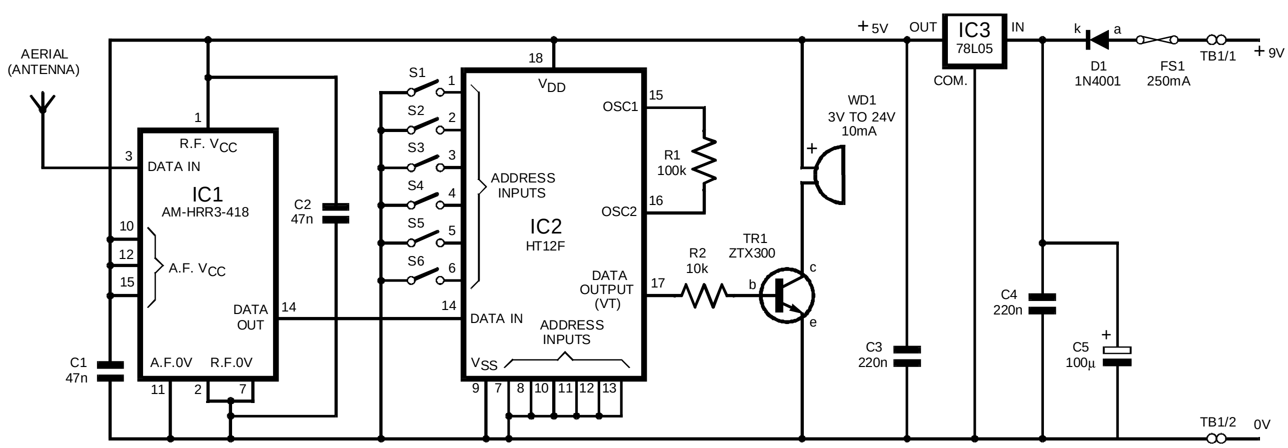


Fig.6. Full circuit diagram for the Receiver section of the Garage Link. The designation "VT" at IC2 pin 17 means Valid Transmission.

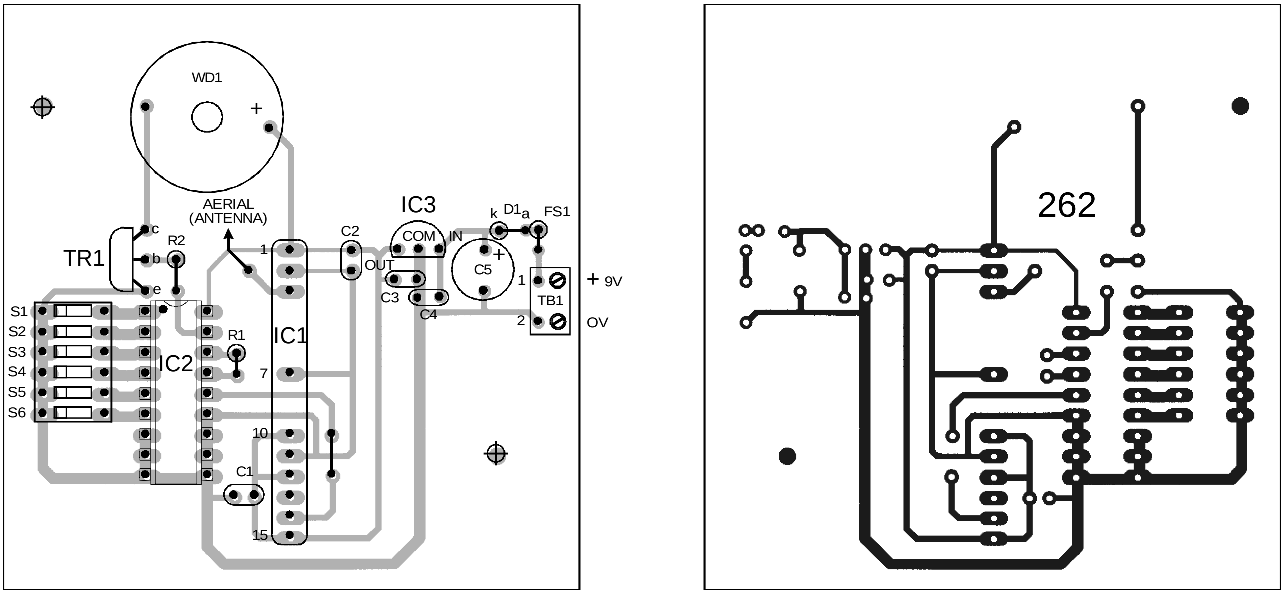


Fig.8. Printed circuit board component layout and (approximately) full size copper foil track master for the Receiver.

divider. Its top arm consists of fixed resistor R1 connected in series with preset potentiometer VR1. The lower arm is light-dependent resistor (LDR) R2.

When the LDR is brightly illuminated, its resistance will be lower than the R1/VR1 combination and the voltage at pin 2 will be less than 3V – that is, less than that at pin 3. With the opamp non-inverting input voltage exceeding the inverting one, the output at pin 6 will be high.

This state is transferred through diode D1 to IC3 pin 14. Whatever the state of IC2 output, IC3 "transmit enable" pin will be made high so operation is inhibited.

FAILING LIGHT

As the light level falls, the resistance of the LDR increases and at some point will exceed that of the R1/VR1 combination. The voltage at the inverting input will then exceed 3V – that is, greater than that at the non-inverting one. The opamp will switch off and pin 6 will go low. This state is blocked by diode D1 so it has no effect on the encoder (IC3) which is now controlled by the astable (IC2) alone.

The exact light level at which the transition occurs is determined by the adjustment of preset VR1. Resistor R5, which is connected between IC1 non-inverting input and the output, introduces a small amount of positive feedback and ensures a sharp switching action at the critical light level.

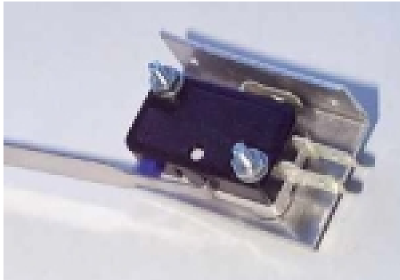
While actually transmitting data the circuit requires some 2mA, but between pulses the prototype used less than 95uA. Due to the short pulse length, the average current is very small. Remembering that when the garage door is closed there is no current drain at all, the overall current needed by the Transmitter is even less.

CONSTRUCTION – TRANSMITTER

Important Note: The design of the aerial is specified by UK regulations. There are two configurations possible but, of these, a *tuned loop* is used here. *The enclosed area must not exceed 700 square mm and it must be integral within the unit – it cannot be placed externally and driven through a feeder.* Radio amateurs please note: *this transmitter is not type approved for use with a quarter wave or helical antenna .*

All components for the Transmitter (apart from the battery pack) are mounted on a single-sided printed circuit board (PCB). The topside component layout and (approximately) full size underside copper foil track master are shown in Fig. 4. This board is available from the *EPE Online Store* (code 7000261) at **www.epemag.com**

Begin construction by drilling the two fixing holes and soldering the IC sockets, DIP switches S1 to S6, and the two link wires in position. One of these is soldered between



The lever-arm microswitch mounted on a small metal bracket.

points A and B. The other is the *test link* (LK1 – C-D-E). The wire should be soldered as shown between C and D for normal operation.

Next, the resistors, capacitors and diodes (taking care with the polarity of capacitors C1, C3 and the diodes) can be mounted and soldered in position. If a 1·5MΩ resistor is not available for R9, connect one 1MΩ and one 470kΩ in series.

In the prototype, resistor R5 (66MΩ) consisted of two 33MΩ units connected in series to make up the value. You could use a single resistor having a value of between 56MΩ and 100MΩ if this is available.

Cut the LDR (R2) leads to a length of about 15mm and solder it in place. Bend the leads through right angles so that the "window" points to the side (see photograph). Solder the positive (red) and negative (black) wires of the PP3-type battery connector to the "+6V" (via switch S7) and "0V" points respectively on the PCB.

LOOP AERIAL

The prototype aerial was made using a piece of light-duty single-core insulated wire cut to a length of 80mm. The end 1mm or so was stripped and the wire bent into a loop. It was then soldered into the "aerial" position on the PCB.

TRANSMITTER MODULE

Before unpacking the transmitter module, remove any

Garage door closed – microswitch arm compressed, power off!

Garage door open – microswitch arm released, power on!

static charge that might exist on the body by touching something which is "earthed" such as a metal water tap. This is because it is a static-sensitive device and such charge could damage it.

Cut its leads to a length of 15mm and solder it in place on the PCB, using minimum heat from the soldering iron. Take care over the polarity – the positive end is identified by a black mark on the body.

Taking the same anti-static precautions, unpack IC2 and IC3. Insert them in their sockets taking care over the orientation. By leaving IC1 position empty for the moment, the light-sensing aspect of the circuit will be disabled and this will simplify testing.

Adjust trimmer capacitor VC1 so that the plates are *not* meshed or only slightly so (look closely at it while rotating the top screw). This gives the minimum capacitance of 2pF, which worked well in the prototype.

RECEIVER

The complete circuit diagram of the Receiver section of the *Garage Link* is shown in Fig.6. The receiver module IC1 requires a 4·5V to 5·5V supply.

The total current requirement of the circuit is 5mA approximately, which could not be maintained by a battery over a long period of operation. This is why a mains power adapter (sometimes referred to as a battery eliminator) is called for.

The power adapter supplies a nominal 9V to the input of voltage regulator IC3, via fuse FS1 and diode D1. The output of IC3 provides the 5V needed by the receiver module, and this is also used by the rest of the circuit. Fuse FS1 prevents possible damage in the event of a short-circuit.

Diode D1 prevents damage if the supply were to be

connected the wrong way round. This is a possibility where plug-in power supply adapters are used, because the output polarity is sometimes uncertain. If the supply was reversed, D1 would not conduct and nothing would happen.

The receiver module is in the form of a single-in-line package – that is, it has only one row of pins. Not all the pins are present and gaps are left where they would have been. The numbering takes into account those which are present as well as those which are not so, although there are 15 numbered "pins", only 10 of them actually exist. The pin layout and designations are shown in Fig.7.

There are separate pins for the positive supply feed to the RF (radio frequency) and the AF (audio frequency) sections. These are pin 1 and pins 10, 12 and 15 respectively. There are also separate ground (0V) connections for these (pins 2 and 7 for RF and pin 11 for AF).

The same power supply is used for both sections, but they are decoupled separately using capacitors C1 and C2. The aerial is connected to IC1 pin 3 (Data In). The amplified data appears at output pin 14.

DECODING

The decoder IC2 is, in many respects, similar to the encoder (IC3) in the Transmitter unit. The receiving code is set up in the same way using a set of DIP switches S1 to S6. The non-settable address pins 7, 8 and 10 to 13 are fixed with a logic state of 0, by tying them to the 0Vline. Pin 9 is connected along with these because it is the 0V input. Data is applied to pin 14 (Data In) from the receiver module output, pin 14.

Resistor R1 connected between pin 15 and pin 16 (Osc1 and Osc2) sets the decoder oscillator frequency. This needs to be approximately fifty times higher than that used in the transmitter section and the specified resistor sets it at 100kHz approximately.

When correct data arrives at IC2 pin 14, pin 17 (Valid Transmission) goes high. Current then flows, via the resistor R2, into the base (b) of transistor TR1 and the buzzer WD1 in the collector (c) circuit operates. Since data is received in short bursts as determined by the Transmitter output, the buzzer will sound with regular bleeps.

CONSTRUCTION – RECEIVER

All components for the Receiver (apart from the supply input socket) are also mounted on a single-sided printed circuit board (PCB). The topside component layout and full size underside copper foil track master are shown in Fig.8. This board is available from the *EPE Online Store* (code 7000262) at **www.epemag.com**

Begin construction by drilling the two fixing holes then solder the terminal block TB1, link wire, IC sockets, and DIP switches S1 to S6 in position. Use pieces of single in-line (SIL) socket for receiver module IC1 – *do not solder this IC directly onto the board.* You could make these by cutting up a dual-in-line socket.

Solder all resistors and capacitors in position taking care over the orientation of electrolytic capacitor C5. Add fuse FS1. In the prototype this was the PCB-mounting type; this is convenient because it will probably never blow.

Follow with diode D1, transistor TR1, regulator IC3 and buzzer WD1, again, taking care over their orientation. Note that the flat face of the regulator is *downwards* and that of the transistor to the *right*. Some regulators have a different pin arrangement so check this point if necessary.

PRELIMINARY SET-UP

Attach a PP3-type battery connector to terminal block TB1, taking care over the polarity. A 9V battery will be used for testing but it will be replaced with the plug-in, mains adapter, power supply at the end.

Solder a piece of light-duty stranded wire 18cm long to the "aerial" point. This corresponds to one-quarter of a wavelength approximately. Note that, unlike the Transmitter aerial, this could be placed outside the case. You could even use a short telescopic aerial, if you wish.

Observing the anti-static precautions again, insert IC2 and the receiver module, IC1, into their sockets. IC1 will only fit one way – that is, with the components side facing IC2. *Take great care when inserting it*. If too much force is used, the pins will bend and possibly damage it. Note also that the pins are fairly long and will not push fully "home".

PRELIMINARY TESTS

Decide on a code for the two units. It does not matter what it is, but the DIP switches (S1 to S6) in each unit must be set in exactly the same way.

Connect a PP3 battery to the Receiver and pull out the aerial into a straight line. Place the two units approximately 2m (6ft approx.) apart. Insert the cells into the Transmitter battery holder and connect it up. Note that the maximum voltage to be used with the Transmitter is 6V – more than that will damage it.

With luck, the buzzer will begin sounding with rapid bleeps! Remember, resistor *Rt* is in the circuit and the time period has been reduced for testing.

If it fails to work, change the alignment of the transmitter aerial. Try moving the units closer together to see if that improves matters. Experiment with the adjustment of capacitor VC1. If it still doesn't work, check that the code switches in each unit are definitely set in the same way. A faulty soldered joint at a DIP switch in either unit could set the wrong code and prevent the system from working.

AT FAULT

If there is still a fault, it is more likely to be in the Transmitter, because this has two distinct sections. These are the encoder and transmitter on one hand and the light sensor (but this part has been temporarily disabled) and astable on the other. If there is a persistent fault, you could try isolating it to one of these sections.

First, remove the ICs observing the anti-static precautions mentioned earlier. Now, change the connection of the "test link" LK1 on the PCB so that C connects to E. This takes IC3 pin 14 to 0V and allows the Transmitter to send data continuously. If it now works, check the earlier stages. If nothing happens, it is more likely that the fault lies in the Receiver. Assuming the two units are operating over a short range, try increasing it. Move them to the point where the buzzer operates intermittently or in a "chirping" way due to periods which lack proper data. Adjust VC1 using a *plastic* trimming tool (a metal screwdriver blade will affect operation) to tune the Transmitter aerial for the best signal. Increase the range to 10 meters and make further adjustments as necessary. Experiment with the orientation of the aerials.

LIGHT WORK

To check the light-sensing stage (IC1), first disconnect the Transmitter battery. Observing the anti-static precautions, insert IC1 taking care over the orientation. Adjust preset VR1 fully anti-clockwise (this means it does not have to be very dark to operate and simplifies testing).

Re-connect the battery and test the system. With sufficient light reaching the LDR (R2) sensitive surface, the buzzer should stop sounding. When the LDR is covered, it should begin again. If this does not work, try covering the LDR more carefully – perhaps sufficient light is still reaching it. Cover the LDR with black opaque PVC tape so that the transmitter works continuously again.

ON TRIAL

With the aid of an assistant, hold the two units in various trial positions to find the best ones. As with any very low-power radio equipment, there will be good and bad spots. Check with the car in the garage. The orientation of the Transmitter loop is important. Set this and the Receiver aerial for best effect.

Do not use metal boxes to house the units – only plastic ones. Metal boxes would screen the circuits and prevent radio waves passing in or out!

FINAL ASSEMBLY – TRANSMITTER

Place the Transmitter PCB and battery holder on the bottom of the box in their correct positions. When deciding on the orientation of the PCB take account of the direction from which the LDR will receive light. Ideally, it should end up pointing towards the garage door so that when this is open, it will receive "outside" light. Alternatively, try to direct it towards a window.

Mark through the fixing holes, remove everything again and drill them through. Holding the PCB in place, a small distance above the base of the box, mark the LDR position. Measure the position of preset VR1 and mark the lid directly above it. Remove the PCB and drill these holes.

The one for the LDR should be about the same diameter as its window. The hole for VR1 should be large enough to allow it to be adjusted from the outside using a small screwdriver or trimming tool. Drill a hole near the right-hand side of the PCB for the wires leading through from the garage door switch.

Before attaching the PCB, drill two holes in the back of the box clear of all internal components. These will be used for attaching the unit to the wall later. Secure the PCB using

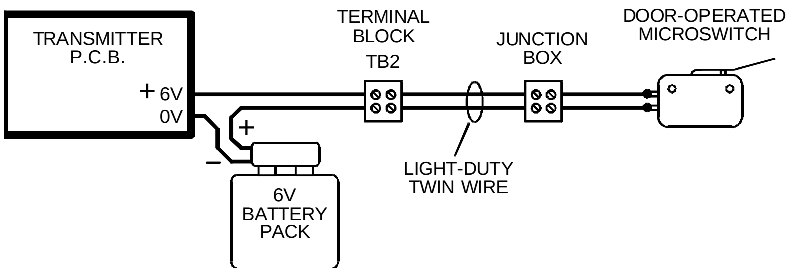


Fig.9. Interwiring between the Transmitter and remote door-operated microswitch.

plastic washers on the bolt shanks. The LDR leads should be bent so that the window lies a few millimeters behind the hole drilled for it. Secure the battery holder using adhesive fixing pads or a small bracket.

– RECEIVER

Disconnect the battery and remove the connector from the terminal block TB1. Place the Receiver PCB on the bottom of its box and mark through the fixing holes. Take it out and drill these through. Measure the position of the buzzer and drill a hole in the lid larger than that in the buzzer itself for the sound to pass through.

Check the type of connector fitted to the mains adapter power supply unit. Drill a hole in the side for a socket of the same type and attach it. Drill two holes in the back of the box (clear of the PCB) to attach it to the wall later. Secure the PCB using plastic washers on the bolt shanks.

Solder two pieces of connecting wire to the power socket. Take care that the correct tags are used. Check the polarity of the power supply unit output and connect the wires to terminal block TB1 observing the correct polarity.

If you are unsure about this, do not worry. If the receiver does not work at the end it will be simply a matter of reversing these wires. If you are using a power supply unit with an adjustable output, you may find that the "6V" setting actually provides over 9V when used under the low-load conditions of this circuit.

Attach the Transmitter and Receiver units in their final positions.

SWITCHED ON

Decide on the switching arrangement for switch (S7) at the garage door. In the prototype, a lever-arm microswitch was used. This was attached to a small aluminum bracket (see photograph) which was, in turn, secured to the doorframe. The microswitch had a large paddle-style lever, which allowed for some tolerance in fitting, although any type could probably be used.

The switch should be operated by some part of the door mechanism, which moves relatively slowly when the door is operated. This will avoid heavy jarring as the door closes.

Hold the switch assembly in position and check that the lever will be pressed to the point where the switch clicks as the door reaches its closed position. Check carefully that this does not interfere with normal operation of the door.

Attach the switch and make any adjustments as necessary. Make sure the switch lever still has some movement left when the door is closed so that it is not placed under any undue strain.

CONNECTING UP

Identify the switch contacts that "break" (open) when the door is closed (that is, the normally-closed contacts). There is usually a diagram of this on the side of the microswitch. Using spade receptacle connectors, attach a short piece of light-duty twin stranded wire to the appropriate tags. This should be sufficient to reach a small junction box (the burglar alarm type is ideal) attached near the doorframe.

Referring to Fig.9, complete the external wiring. Any light-duty twin stranded wire will be suitable. You will need to place a 2-way piece of screw terminal block TB2 inside the transmitter case.

Cut the red battery connector wire and connect its free ends to the terminal block. Connect the switch wires to the block, via the junction box, as shown. If two switches are used for two doors, connect them in parallel.

Connect the power supply unit to the Receiver and test the whole system. If it fails to work, reverse the polarity of the power supply wires.

The Receiver aerial wire could be either routed around the inside of the case (make sure the end is insulated so that it cannot make metallic contact with any internal components. Alternatively, it can be allowed to hang outside through a small hole.

LIGHTING-UP TIME

It is now time to remove the tape from the LDR in the Transmitter so that the light-sensing part operates. Wait until it is dark enough and, with the lid in place and the garage door open, adjust preset VR1 so that the system just responds at this point.

You will find that the light level at which the unit starts to operate (going dark) is not quite the same as that at which it stops operating (going light). This is due to the effect of feedback resistor R5 in the Transmitter. If the effect is too pronounced, increase its value or remove it.

You may find that the LDR "sees" the garage light when this is switched on. Of course, this would hold the buzzer *off*. This would probably be an advantage because if someone was working in the garage at night with the door open, the buzzer would not sound.

If you want it to operate under these circumstances, shield the LDR so that the garage light does not reach it. Bending its leads so that it lies further behind the hole and directing the unit more carefully at the source of "outside" light will also help.

Remove the Transmitter lid and cut through one of the leads of test resistor, *Rt*. Move the cut ends apart to prevent them from touching. The buzzer should now give a short bleep every 45 seconds approximately.

ON APPROVAL

Before putting the system into permanent service, it is important to display a mark on the transmitter stating that it conforms to DTI Specification MPT1340. This must state the wording "MPT1340 W.T. License Exempt". The size must not be less than 10mm x 15mm and the figure height must not be less than 2mm.

MICRO PICSCOPE by JOHN BECKER

Visual signal monitoring with frills!

It is astonishing what opportunities are continuing to be revealed for the recently introduced PIC16F87x series of microcontrollers. This *Micro-PICscope* is a prime example of a design idea whose implementation was greatly simplified by using one of these devices.

The *Micro-PICscope* is a handy little item of test gear and of benefit to anyone's workshop. Using an alphanumeric liquid crystal display (LCD), it is basically a signal tracer, but one with the great advantage that it shows a representation of the signal waveform that is being traced. This is shown across eight of the LCD character cells and is a real-time trace of the monitored waveform.

Not only that, the display also shows the frequency of the signal being monitored, and its peak-to-peak voltage. The frequency range covered is basically for audio, but frequencies well to either side of this range can be traced.

Several ranges of control are offered by switch selection, covering the sampling rate, and synchronization on/off for the 'scope display. The signal input is switchable to provide different maximum peak voltage monitoring ranges. Selection of AC or DC input is provided.

The entire design requires only two ICs, a PIC micro and an opamp, plus a 2-line by 16-character LCD. An optional third IC provides power regulation if required.

A typical example of the LCD screen display is shown below.

Example of the screen display obtainable on the LCD module.

DESIGN HISTORY

Some 12 or more years ago, when the author first became familiar with "intelligent" alphanumeric LCDs, it became apparent that by using the internal programmable character generator, their screens might be capable of displaying a simple representation of a signal being monitored. *(There is a GREAT article on these displays in the EPE Online Library at* **www.epemag.com***, Ed.)*

He had already designed and published a similar purpose unit based on multiplexed LED (light emitting diode) displays. In that unit (*PE* June '92), an LM3914 bargraph IC was used in conjunction with shift registers and digital multiplexers to portray a waveform across four 5 x 7 bit matrixed LEDs. It was very effective, although somewhat power hungry.

At the time though, microcontrollers were an unknown to the author and a method by which an LCD screen could be similarly used eluded him. Whereas LED matrices require only logic control, alphanumeric displays require a variety of data commands to be provided under program control.

For some simple operations LCD commands can be generated using codes pre-programmed into an EPROM (electrically programmable read only memory). This technique had already been successfully used by the author in a real-time *Morse Code Decoder* (*EE* Jan '87), but did not lend itself to circuit board signal tracing and monitoring.

The introduction of the versatile PIC16x84 microcontroller re-sparked interest in the idea, and it could have been done using that PIC with a separate analogue-to-digital converter (ADC). Then along comes the PIC16F87x family – with built-in ADC. Bingo, the idea was now as good as

constructed to full workshop working order as a single chip design – apart from writing the command program, of course!

CIRCUIT DETAILS

In fact, as you will see from the complete circuit diagram for the *Micro-PICscope* in Fig.1, the practical implementation of the idea has been expanded a bit to use more than just a microcontroller (IC2). A buffering and gain setting opamp (IC1a) has been included as well. So too has a 5V regulator (IC3), allowing the unit to be powered from 9V or 12V supplies. If you have an existing well-stabilized 5V supply, IC3 may be omitted.

The signal being monitored is brought into opamp IC1a. As set by resistors R1 to R3, the gain can be selected by switch S1 to be x1 (unity – via R2) or x10 (via R1). Other gain-setting values could be chosen instead. For example, a 10kΩ resistor could be used for R3 instead of a 100kΩ. This would provide switchable gains of unity and 1/10.

Switch S2 provides selection of AC or DC signal coupling, switching capacitor C1 in and out of circuit. The output from IC1 to the microcontroller is DC coupled. You will spot that the opamp is

Completed Micro-PICscope showing general layout of display and controls.

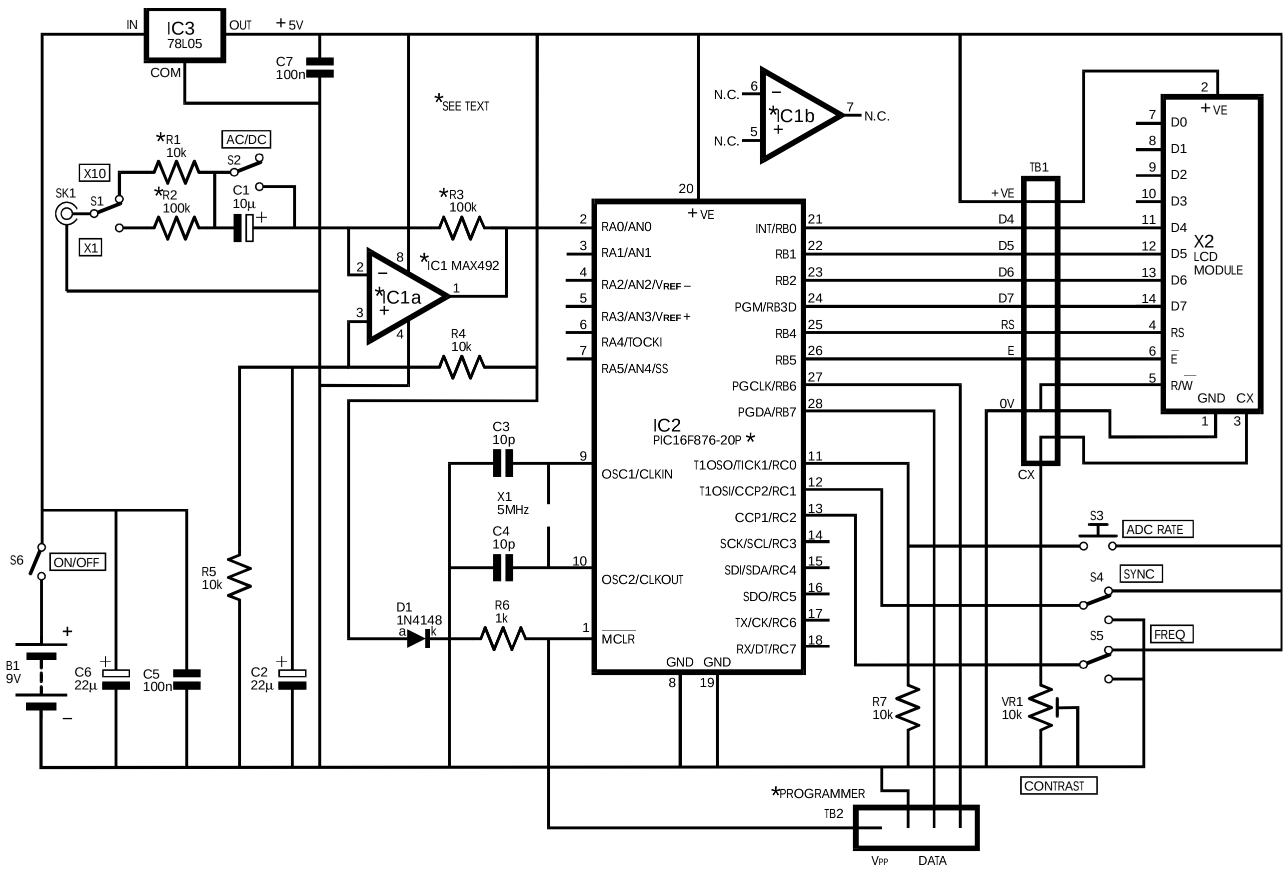


Fig.1. Complete circuit diagram for the Micro-PICscope. The voltage regulator IC3 is optional – see text.

used in inversion configuration. Software ensures that the signal is seen the "right way up"!

A MAX492 dual opamp is used for IC1, with the second half ignored. This device is part of the author's stock "library" and has proved itself for its nearly rail-to-rail output swing. The circuit has also been used with a TL082 device, which provides good frequency range, although does not offer full rail-to-rail output (typically more like 4V swing for a 5V split supply as used here – split by resistors R4 and R5).

MICROCONTROLLER

Microcontroller IC2 is a PIC16F876 device, operated at a clock rate of 5MHz, as set by crystal X1. Because of this clock rate, the 20MHz version of the PIC should be used. The "standard" version has a maximum guaranteed clock rate limit of 4MHz. However, you may find it interesting to note that the author has successfully used the 4MHz version at rates well in excess of 5MHz.

The PIC16F87x family has been discussed at length in previous issues of *EPE* and the '876 will not be described in detail here. Suffice to say that it has three input/output (I/O) ports, one of which, PORTA, can be used for analog-to-digital conversion via five of its pins (RA0 to RA3, plus RA5). In this design, only RA0 (pin 2) is used, its input being taken directly from the output of opamp IC1a at pin 1.

Internally, the PIC is programmed by the software so that the voltage reference for the ADC is taken as 0V to 5V (the power line voltage range). Consequently, an A-D conversion value of 255 results when the input to RA0 is at the positive supply line level of 5V. A result of zero occurs when the RA0 input is at 0V.

Output to the LCD (X2) is via PORTB, using lines RB0 to RB5 to control the display in conventional 4-bit mode. Connections to the LCD are via the terminal pin block TB1. The order of the pins, both physically on the printed circuit board (PCB) and in terms of program control, is identical to that used by the author in many of his recently published designs. Display contrast of the LCD screen is set by preset VR1.

EXTERNAL CONTROL

External control of the PIC's monitoring and timing functions is actioned via PORTC, through pins RC0 to RC2. The functions controlled are the ADC sampling rate (via S3), waveform synchronization on/off (S4), and frequency counter display on/off (S5). These will be discussed later.

Pins RB6 and RB7, whilst not actively used by the design itself, can be used to program the PIC via a suitable programmer, such as *PIC Toolkit Mk2* (May-June '99). The MCLR pin (master reset) is normally powered at 4·3V (5V – 0·7V) via diode D1 and buffering resistor R6. This allows programming voltage control without disturbing the normal 5V supply rail from voltage regulator IC3.

Terminal pin block TB2 provides access to MCLR, RB6, RB7 and the 0V common line. The pin order on the PCB is the also same as that used by the author in previous designs. This will be welcomed by those who have established a plug-in link between *Toolkit Mk2* and such designs! (The author intends for all his future PIC designs to use this same pin configuration for LCD and programming connections.)

CONSTRUCTION

Details of the PCB component and track layouts are shown in Fig.2. This board is available from the *EPE Online Store* (code 7000259) at **www.epemag.com**

Regular readers will know this author's preferred constructional order: wire links, resistors, diodes, small capacitors, IC sockets and then on upwards in order of component size.

Dual-in-line sockets should be used for IC1 and IC2. Note that microcontroller IC2 is the narrow version (0·3in width between pin rows, as opposed to 0·6in).

Details of the switch and signal input connections are also shown in Fig.2. Socket SK1 may be a different type to that shown if preferred.

The LCD module might have one of two possible pin connection arrangements. They are shown in Fig.3.

As always, do a thorough check of the component positioning, orientation and solder joint integrity before applying power. Do not insert IC1, IC2 or the LCD until the output from regulator IC3 has been validated, exactly 5V (within a few millivolts) for a supply between 7V and 12V.

An output voltage from IC3 other than 5V will usually indicate a fault in construction – too high and IC3 is wrongly inserted, too low and there may be a short circuit somewhere on the board.

FIRST RUN

When happy about the power supply, test the circuit with IC1, IC2 and the LCD plugged in (correctly!). Set switch S4 (Sync) off and S5 (Frequency) on. When power is applied, the PIC first goes into an LCD initialization routine, in which it sets the LCD for 2-line 4-bit mode.

Following this, text messages similar to those in the photographs should appear. The signal trace display in the top left LCD character cells should show as a straight line about half way up the screen. Adjust preset VR1 to set the screen contrast (you may see nothing at all until you have adjusted it).

Having read the sections all about the control program, you can then feed in an audio signal, play with the switches, and see the results on screen. The input signal amplitude should be selected so that the majority of the LCD vertical pixel range is used.

ENCLOSURE

A small plastic box was used to house the prototype. The PCB has been designed so that the LCD can be mounted above it using stand-off pillars, although the prototype did not use this option.

The rectangular viewing slot was cut by first drilling small perimeter holes and using a file to smooth the edges to shape and size. Holes must also be drilled to suit the switches and input socket. The prototype used a 3·5mm jack socket for the power input, but other techniques, such as a battery connector, can be used.

A-TO-D CONVERSION

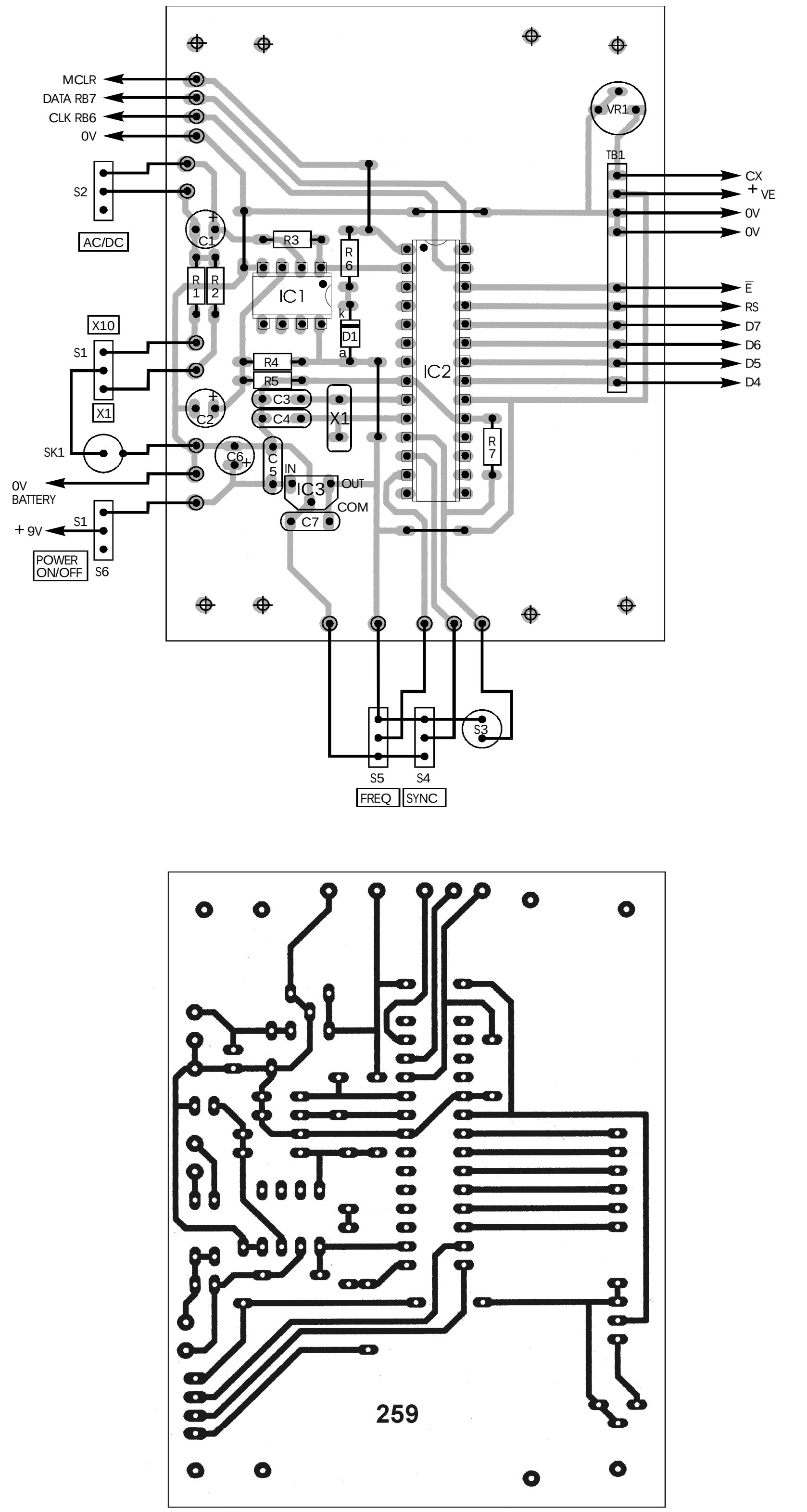


Fig.2. Printed circuit board component layout, wiring to the off-board components and (approximately) full-size copper foil master for the Micro-PICscope.

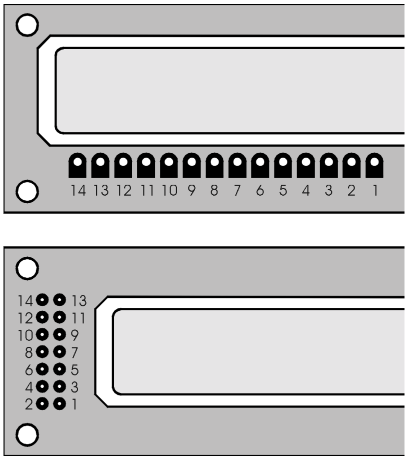


Fig.3. Pinout arrangement of the two basic LCD formats.

Basic A-to-D conversion using a PIC was discussed in the *Mini PIC16F87x Tutorial* of Oct '99. A simplified version of the routine described there is used here:

In the START routine while in PAGE1, register ADCON1 is set with the binary value of %00000101, which tells the PIC that the 2-byte ADC register is to be justified left, with RA0 as an analog input referenced to +VE and 0V.

Then, back in PAGE0, by loading register ADCON0 with a binary value of %010000001, ADC conversion is activated at an oscillator rate of one-eighth of the clock rate (Fosc/8).

(Readers who write their own PIC software should note that in order for PAGE commands to be used with the *Toolkit* programmer and the PIC16F87x family, bit RP1 of the PIC's STATUS register must be set to 0 – as it is in the START routine of the *Micro-PICscope* source code.)

A single ADC sample is taken when the command **BSF ADCON,GO** is issued, where the quaint GO term (Microchip's description!) refers to bit 2. Sampling and conversion are not quite instantaneous and the program repeatedly polls the GO bit until it goes low, signifying an end to the conversion process. There are several subroutines which are used in the program to perform this task, one of them being:

```
WAITS1: BTFSC ADCON0,GO
        GOTO WAITS1
        MOVF ADRESH,W
```

When the GO bit is clear, the command **MOVF ADRESH,W** retrieves the high byte of the 2-byte conversion result. Because the display is only eight pixels high, the low byte is not needed (see the *Mini Tutorial*, or the PIC16F87x data book, for details of the conversion result format options).

The value held in ADRESH (and now also in W) is that which represents the voltage level of the signal being sampled. It cannot yet, however, be put out to the LCD screen, there's a great deal of work to be done first! For the moment, this value is simply stored in one of a set of temporary memory locations. The conversion and storage is performed 128 times before further action is needed.

DISPLAY PRINCIPLE

Before that "further action" is described, it is first necessary to understand the concept behind the way in which a waveform can be displayed on the LCD by making use of its character generator.

You already know that the LCD used here has two display lines each having 16 character cells. Each of these 32 cells consists of a matrix of LCD pixels, arranged as five across by eight down (see Fig.4a).

Normally, the LCD module places pre-programmed (as part of the module's control chip manufacturing process) alphanumeric data into these cells according to command codes from an external source, a PIC in this case.

However, the module has the facility to allow eight characters to be "designed" by the user and called as well as the standard alphanumeric set. These characters are stored at module address locations 0 to 7.

At first sight, when examining the LCD data sheet, it might appear that address locations 8 to 15 can also be used to hold custom characters as well. Regrettably for an application such as this PICscope, addresses 8 to 15 only hold repeats of the data at addresses 0 to 7. Thus only eight addresses can be used for alternative character data, hence the PICscope only having eight cells for waveform display.

Eight cells each having five pixels horizontally allows 40 waveform samples to have their values plotted at eight vertical pixel levels.

The reason that 128 samples are taken even though only 40 will be displayed from each block is to allow for frequency and amplitude values to be more readily established.

CHARACTER GENERATOR

The way in which data for a character cell is evaluated is illustrated in Fig.4b. Each of the seven rows making up the cell display are treated individually. The five pixels of each row are numbered from 4 to 0, allowing a 5-bit binary number to be compiled. Logic 1 in a bit

position turns on the equivalent pixel, while logic 0 turns it off.

Having established which bits are to be active, the 5-bit binary number for each row (expanded to 8-bit with zero in bits 7 to 5) is sent to the required character generator address, of between 0 and 7. The same procedure can be used for the other seven possible addresses, each of them storing different data, as appropriate.

When character data is being generated in this way, the LCD is first told that the data about to arrive is destined for the character generator rather than for the screen display. In the program the initial command is given by:

```
MOVLW %01000000
CALL LCDLIN
BSF RSLINE,4
```

which sets the character generator to address 0 from which address onwards the "designed" data is to be stored, the address incrementing each time a data byte is written to the LCD. The LCDLIN call is to one of several standard routines, which the author wrote some years ago to send various commands and data to an LCD module.

For all eight character cells to be fully programmed, 8 x 8 = 64 bytes of data are written to the character generator.

Once the character generator has been programmed, the data held at each of the eight address blocks can be called to the screen by simply accessing that address in the same way that "normal" alphanumeric data is accessed.

For example, to display letter "A" on screen you might use either **MOVLW 'A', CALL LCDOUT**, or **MOVLW 65, CALL LCDOUT**, the value of 65 being the ASCII value for capital letter 'A'. In both cases the character held at character generator address decimal 65 would be displayed on screen, which,

COMPONENTS

Resistors
- R1, R4, R5, R7 10k (4 off)
- R2, R3 100k (2 off)
- R6 1k

All 0.25W 5% carbon film

Potentiometer
- VR1 10k miniature round preset

Capacitors
- C1 radial electrolytic, 16V
- C2, C6 22u radial electrolytic, 25V (2 off)
- C3, C4 10p ceramic, 5mm pin spacing (2 off)
- C5, C7 100n ceramic, 5mm pin spacing (2 off)

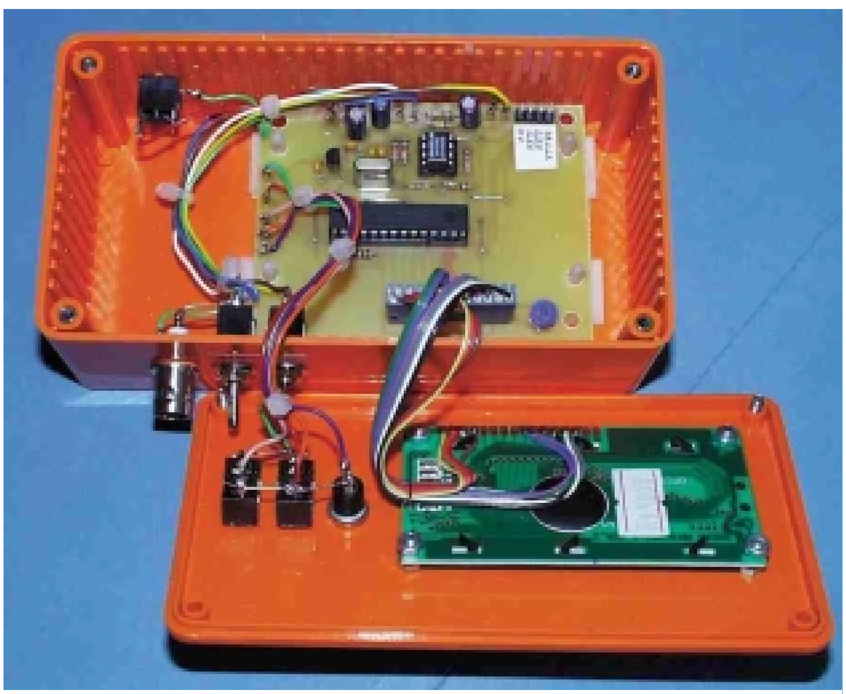
Semiconductors
- D1 1N4148 signal diode
- IC1 MAX492 dual opamp
- IC2 PIC16F876-20P microcontroller (20MHz version, 0.3-inch width) preprogrammed
- IC3 78L05 +5V 100mA voltage regulator (see text)

Miscellaneous
- S1, S2, S4, S5 miniature s.p.d.t. toggle switches (4 off)
- S3 miniature push-to-make switch
- S6 miniature s.p.s.t. (or s.p.d.t.) toggle switch
- SK1 BNC socket (see text)
- X1 5MHz crystal
- X2 2 line x 16 characters per line alphanumeric crystal display

Printed circuit board available from the *EPE Online Store* (code 7000259) **www.epemag.com**; powere supply connector (see text); plastic case, 150mm x 80mm x 50mm; 8-pin DIL socket; 28-pin DIL socket; 1mm terminal pins (or strips) for TB1 and TB2; PCB and LCD supports (8 off); connecting wire; cable ties; solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only **$31**



Completed unit showing the LCD module mounted on the lid of the case and wiring to the PCB.

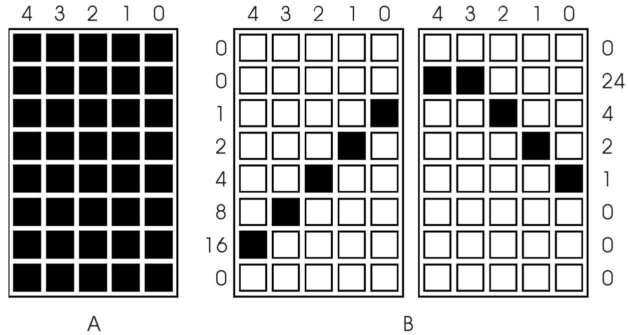


FIg.3(a). LCD character cell matrix with all pixels on, (b) example of waveform representation across two character cells.

fortunately for us all is indeed the letter "A".

Similarly, to show the character newly programmed into address 3, the commands would be **MOVLW 3, CALL LCDOUT**.

The data held at character generator addresses 0 to 7 can be changed as often as required. In this design it is typically changed about twice per second (faster with S4 and S5 off). All data at these addresses is lost when power is switched off.

WAVEFORM CHARACTERS

When a full block of samples has been converted and stored, the data is then analyzed for amplitude and compiled into 64 bytes for sending to the character generator. Row 8 is the top row and (naturally) represents the highest voltage range that can be displayed. The display is, of course, compressed to one-eighth of the conversion value received.

The analysis procedure is far more complex than can be described here. It is not just a matter of ascertaining which row a value should be allocated to. The result also has to be "doctored" so that the active pixels are seen to be as close to a continuous line as possible.

For instance, suppose the waveform is alternating rapidly between high and low levels at a rate faster than the sampling can keep pace with. Without corrective action, you might only see pixels on the upper and lower lines, those between remaining blank.

The corrective action fills in those blank pixels so that they appear as though they naturally follow on from each other. This was an extremely difficult process to write the program for! Even experienced programmers might have difficulty analyzing the way in which the source code has been written – be warned!

Close-up of typical screen display. There are three rates, the maximum counting frequency is about 17kHz.

However, you don't need to understand the program in order to use it. Just load it into your PIC (or buy a ready-programmed PIC – see later).

Although there is a great deal of processing being carried out, each batch of sampled data is displayed in rapid succession and really does give a "real-time" display of what is happening in a monitored circuit.

FREQUENCY AND AMPLITUDE

Each batch of data is also analyzed for waveform frequency and peak-to-peak amplitude values.

Amplitude is easily determined by simply looking for the maximum and minimum conversion values and then relating them to the maximum possible sample level of 255. The latter, as said earlier, represents the positive line level, which has been assumed to be exactly 5V. If you need greater accuracy for signal level voltages use your multimeter to read them! The PICscope is only intended for providing an approximate value (but it's still pretty accurate).

Note that the PIC does not monitor which gain setting has been selected. It simply reports the voltage it finds on its RA0 pin. You must mentally adjust the value shown if the gain is

other than unity.

Frequency is assessed by counting the number of times the voltage level crosses a preset threshold value. The result is then divided by two to obtain the equivalent number of cycles per batch, the rate of data acquisition being pre-determined by the sampling rate, which in turn is relative to the master clock rate.

Much effort went into writing the software so that relative timings were maintained consistently, irrespective of conditional branch timings in the sampling routines.

There are three rates at which the ADC can be set to sample waveforms, selectable by pressing switch S3. The rates cycle as a repeating group of three, numbered from 0 to 2. The number of the selected rate is shown at the top right of the screen. It is not a representation of the frequency range covered.

The rates are set according to the value by which the master clock oscillator is divided via the ADCON0 prescaler. This value is set by bits 6 and 7 in the ADCON0 register. Rate 0 sets Fosc/2, rate 1 sets Fosc/8, rate 2 sets Fosc/32. The routine which reads S3 and sets the bits commences at label **TESTIT**, following on into **GETRATE**, near the end of the source code listing.

FREQUENCY CALCULATION

Relating the ADCON0 sample rate to the actual frequency of the signal has to take into account the time taken for all the commands in the sampling routine to be performed. As experienced programmers will acknowledge, such matters are not always

Completed circuit board mounted on self-adhesive plastic stand-off pillars.

readily calculated (friend and *EPE* author Andy Flind has researched heavily into this – we hope he'll one day share it with us all!).

The solution here was to count the swings above and below the threshold level and then divide the answer by a conversion factor, with a separate factor for each of the three sampling rates.

Using a subtractive technique, the conversion involves fractions, which are fixed in the software as two-byte binary numbers.

For example, for Rate 0, the MSB is set at decimal 85 and the LSB at 70, which has an equivalent decimal value of 21830 (256 x 85 + 70). From this value is repeatedly subtracted the count value determined when counting the swing changes, each successful subtraction incrementing a counter. Thus the cycle count is divided into the conversion factor, the secondary counter providing the answer. The result is remarkably accurate. (MSB and LSB, incidentally, mean Most and Least Significant Bytes, respectively.)

During prototype testing, the unit was fed with a frequency of 4000Hz and the "fraction" values repeatedly adjusted by trial and error until the LCD also showed a value of 4000Hz.

Having established the values for the three ranges, the input frequency was raised to see how far accuracy was maintained, the results were:

Rate	Generator	Display
0	17007Hz	16984Hz
1	17007Hz	16998Hz
2	5827Hz	5812Hz

Beyond those frequencies, the unit began to display harmonic frequency values because the generator rate exceeded the rate at which the waveform could be sampled.

The values programmed into the unit depend, of course, on the exact frequency at which the crystal controlled oscillator functions. However, crystal controlled oscillators, while not being perfectly tuned to a given frequency, do stick closely to it.

Consequently, other units should achieve results that are not too different from the author's.

Those who which to experiment are referred to the sub-routines at **GETFREQ0**, **GETFREQ1** and **GETFREQ2**, where the preset values can be changed. The program will naturally need to be re-assembled and reprogrammed into the PIC.

Analysis of the peak-to-peak and frequency values can be switched off using S5. This speeds up the rate at which the screen is fed with a fresh waveform display.

SYNCHRONISATION

Switch S4 turns the waveform synchronization facility on and off. When synchronization is on, before each sampling batch is started the software waits until the waveform voltage has twice passed through a preset trigger level. Only then does it start sampling the rest of that batch.

This facility allows the waveform display to start about half-way up the screen, providing a degree of stability to a repetitive waveform. Inevitably, the process increases the wait period before each new display is shown. There is a time-out counter, which prevents the system from "locking-up" should the waveform not cross the sync thresholds.

It is best to start off sampling any new signal with sync off, only turning it on once adequate signal levels are being received. The source routines, which control sync start at label **WAITS1**. The full batch sampling routine commences at **WAITAD0**.

IN THE PIPELINE

That, in a nutshell, is really all there is to tell about this astonishingly simple signal monitor (simple in hardware terms – but certainly not regarding software writing!). Designing it has fulfilled one of the author's ambitions. Software is in TASM.

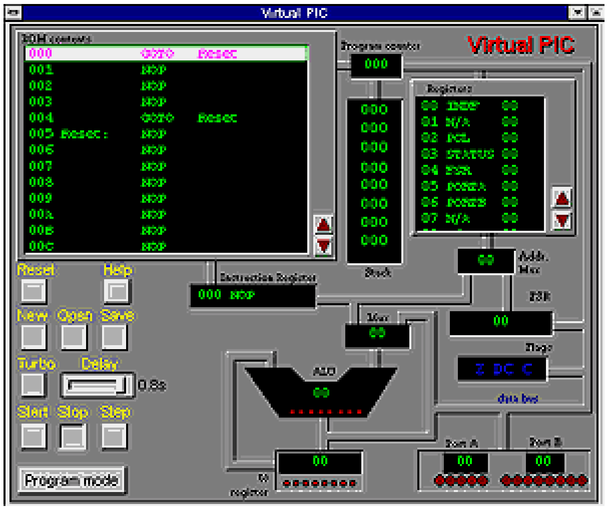
Another yet to be fulfilled is to design a more advanced LCD based scope, which will give far greater resolution to the waveform shapes displayed. Such a design, though will have to wait until the exorbitant cost of LCD graphics displays comes down greatly!

What is in the pipeline, however, is the *Virtual PICscope* in which one of the PIC16F87x family is used to sample two waveforms simultaneously and output the data to a PC computer for display on its screen.

Finally, if you have any ideas for PIC-based workshop designs (or any other type of design, of any sort), please let us know.

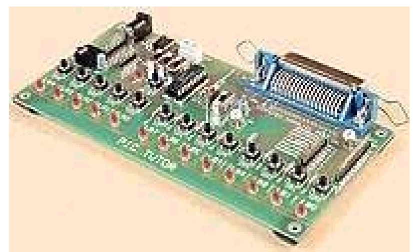
Go to next section

Interested in programming PIC microcontrollers?



This interactive presentation uses the specially developed Virtual PIC simulator to show exactly what is happening as you run, or step through, a program. In this way, the CD brings the EPE PIC Tutorial series to life and provides the easiest and best-ever introduction to this subject.

Nearly 40 tutorials cover almost every aspect of PIC programming in an easy-to-follow sequence.



Deluxe PICtutor Hardware

HARDWARE: Whilst the CD-ROM can be used on its own, the physical demonstration provided by the PICtutor development Kit, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work once you have mastered PIC software writing.

Two levels of PICtutor hardware are available -- Standard and Deluxe. The Standard unit comes with a battery holder, a reduced number of switches, and no displays. This version will allow you to complete 25 of the 39 tutorials -- it can be upgraded to Deluxe at a later date, by adding components, if required.

The Deluxe development kit also has a battery holder (so it can be used around the world), all switches for both PIC ports, plus LCD and 4-digit 7-segment LED displays. It allows you to program and control all functions and both ports of the PIC, and to follow all 39 tutorials on the CD-ROM.

All hardware is supplied fully built and tested and includes a PIC16F84 electrically erasable programmable microcontroller.

PRICING: **CD-ROM (Hobbyist/Student): $70 US Dollars (plus S&H)**
Standard PICtutor Development Kit: $75 US Dollars (plus S&H)
Deluxe PICtutor Development Kit: $160 US Dollars (plus S&H)

Visit the EPE Online store now to BUY!

MINIMUM SYSTEM REQUIREMENTS: PC with 486/33MHz or higher, VGA+256 colors or better, CD-ROM drive, 8MB RAM, 8MB free space on hard disk. Windows 3.1/95/98/NT, mouse.

Ingenuity Unlimited

ROLL-UP, ROLL-UP!

Ingenuity is our regular round-up of readers' own circuits. We pay between $16 and $80 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas must be the reader's own work **and must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. They could earn you some real cash and a prize!

Win a Pico PC-Based Oscilloscope

- **50MSPS Dual Channel Storage Oscilloscope**
- **25MHz Spectrum Analyzer**
- **Multimeter**
- **Frequency Meter**
- **Signal Generator**

If you have a novel circuit idea which would be of use to other readers, then a Pico Technology PC based oscilloscope could be yours.

Every six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners up.

PC Controlled DC Motor – Keyboard Control

A PC can be used to control the speed and the direction of a DC motor using the circuit of Fig. 1 along with the brief BASIC listing provided. The circuit is used to interface a DC motor to the parallel port (LPT1) of an IBM-compatible PC. It consists of complementary transistors connected in an H-bridge network. Four diodes are used to provide a free-wheeling action.

Two general-purpose small-signal transistors TR5 and TR6 (type 2SC1483, or perhaps a BC548 or equivalent – *ARW*) are used to interface the power driver stage to the parallel port of the PC. The data bits D0 and D1 (pin 2 and pin 3) of the parallel port are used to drive the bridge circuit, whilst pin 25 is referenced to the ground of the bridge power supply. A simple QuickBasic program to run the DC motor at any speed and in any direction is given in Listing 1. The address of the parallel port is 378H. When a low on data bit D0 and a high on data bit D1 is sent, this switches transistors TR1 and TR3 on. The result

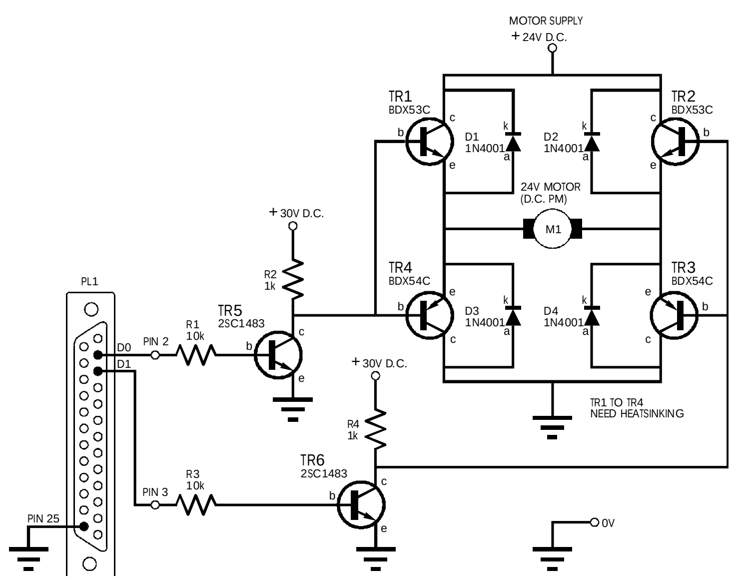


Fig.1. Circuit diagram for the PC Controlled DC Motor Speed Control.

is a current flow through the motor in one direction.

When a high on data bit D0 and a low on data bit D1 is sent, this switches transistor TR2 and transistor TR4 on instead. A current flows through the motor in the opposite direction hence changing its direction of rotation.

Speed Control

The speed of the motor is controlled using pulse width modulation through software. If TR1 is on for example (D0 = low) then current flow through the motor is controlled by switching on alternately the transistor TR2 and TR3. The duration of two FOR TO NEXT loops in the program determines the speed of motor. If the duration of one FOR TO NEXT loop is increased, then the duration of the second FOR TO NEXT loop is decreased accordingly to maintain constant overall loop timing. This results in fixed-frequency output pulses at data bit D0 or data bit D1. The pulse width of the output is controlled by the loops' timing hence controlling the speed of motor. In my case the QuickBasic program running on a Pentium 166MHz PC produced a frequency of about 7kHz at the output, with the speed and direction of the motor controlled by the function keys F1 and F2. The H-bridge T0220 power transistor types shown are rated for 3A and alternative types could readily be used.

M T Iqbal
Rawalpindi, Pakistan

Listing 1: Motor Speed Controller BASIC Program

```
ON KEY(1) GOSUB Speed
KEY(1) ON
ON KEY(2) GOSUB Direction
KEY(2) ON d = 1: h = 500: M =
      0

INPUT "Speed 0-500 = "; s
20 FOR i% = 0 TO h - s: NEXT
      i%
OUT &H378, d
FOR j% = 0 TO M + s: NEXT
      j%
OUT &H378, 0
GOTO 20

Speed:
INPUT "Speed 0.500 ="; s
RETURN

Direction:
```

Omnidirectional Pendulum – In The Swing

A pendulum swinging in a single plane is highly predictable, and can easily be enhanced electronically. An omnidirectional pendulum, however, falls towards its center of gravity at different velocities and from many different angles, thus posing a greater electronic challenge.

My Omnidirectional Pendulum described here is continually in motion, swinging rapidly through its center, or occasionally spiraling around it or bouncing away from it. It will form an interesting novelty display.

A neodymium (super-strength) permanent magnet is suspended from a point by an inelastic line, which prevents the magnet from jumping to the core of an electromagnet L1. The electromagnet is fixed below the pendulum at its center of gravity, see Fig.2b.

The pendulum's length of swing is about 25cm and the point of suspension is 25cm to 50cm above the electromagnet (28cm is recommended). The magnet should pass with about 5mm clearance above the electromagnet's core.

The electromagnet was salvaged from a 12V 200 ohm miniature mains relay, and is polarized to repel the pendulum when overhead. The magnet used was a small slug about 8mm long and 4mm in diameter. *(Consider a small voice coil magnet from an old speaker. ARW.)*

A network of miniature glass reed switches, S1 to S15, surrounds the electromagnet and detects the incoming pendulum. The trigger network is built by soldering the reed switches to a *thin* wire perimeter (thick wire might cause the magnet to jump to the wire) at 2cm intervals to form the outer circle, see Fig.2c.

A thin wire ring is then soldered around its center to produce a circle of reed switches of about 11cm in diameter. The trigger network should be laid flush with the top of the electromagnet's core, and wires taken from its inner and outer rings to the rest of the circuit.

Circuit Detail

Referring to the circuit diagram of Fig2a, as the pendulum falls towards the trigger network's outer perimeter, monostable timer IC1 pulses and triggers 1C2a, which in turn disables the 555 monostable at pin 4 until the pendulum has crossed the entire trigger network.

At the same time, IC1 triggers 1C2b, via diode D3, which powers the electromagnet using transistor TR2. In order to kick-start the pendulum should it stall in a circular pattern of motion (particularly if a longer pendulum is used), components TR1 to C5 are included, causing the magnetic field to collapse at intervals indicated by LED D6. (It may be found that these components can be omitted.)

To set up, centralize all three presets VR1 to VR3 then power up (there will be a short delay before the pendulum kick-starts). Adjust preset VR1 so

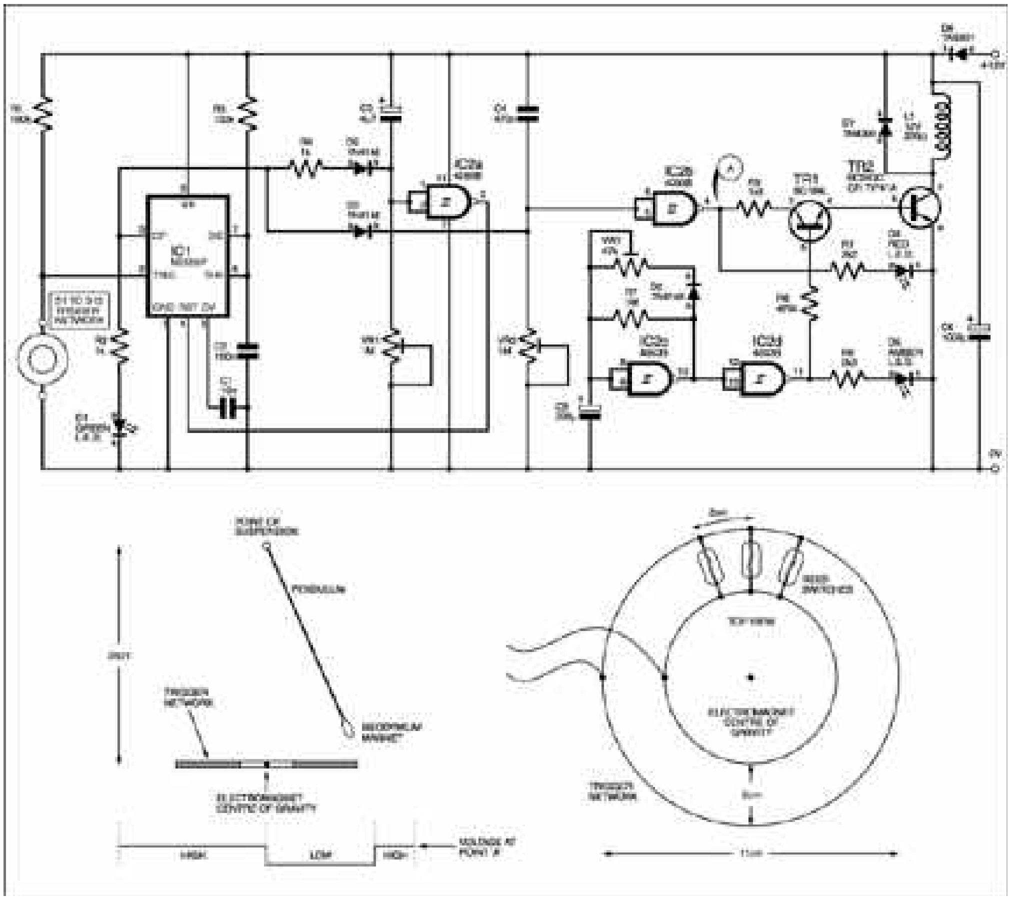


Fig.2. (a) Circuit diagram for an Omnidirectional Pendulum, (b) pendulum and magnet positioning and (c) reed switch arrangement surrounding the magnet.

that green LED D1 pulses once only as the pendulum falls towards the center of gravity – not as it shoots away.

Some experimentation is needed using preset VR2 to synchronize the electromagnet's repulsion with the pendulum's swing, as indicated by LED D4 (note that too vigorous a swing may render the kick-start useless).

A 12V mains adapter is recommended as a power supply, since batteries would soon be exhausted.

Rev. Thomas Scarborough
Cape Town, South Africa

Brushless Fan Speed Control – Fine Tuning

It may not be generally realized that the speed of brushless fans commonly found in computers can be controlled down to just two or three revolutions per second if necessary. This could allow their use in other applications such as displays, lighting effects, or even driving the "Nipkow Disk" described in *Ingenuity Unlimited* December 1999.

The motors within these fans generally consist of an outer revolving armature containing permanent magnets surrounding a static inner coil assembly. The coils are switched sequentially to produce the rotation by an internal electronic circuit, using Hall Effect devices to sense the position of the magnets. Although the motor speed can be reduced to some extent by lowering the supply voltage, a point is quickly reached where the voltage becomes too low for the electronics to operate, so it simply stops.

Much lower speeds can be achieved with a pulse-width modulated (PWM) supply where the power is applied as brief pulses of the full supply voltage, with a constant frequency but a variable width. The circuit of Fig. 3 has been used successfully to achieve this.

How It Works

The circuit works as follows. Opamp IC1a acts as an integra-

tor and IC1b as a comparator with hysteresis set by resistors R4 and R5. Together these two circuit elements form an oscillator with a triangle wave output. Note that the triangle wave from the output of IC1a is applied to the inverting input (pin 2) of IC2, whilst the non-inverting input of IC2 is connected to a control voltage set by VR1, the speed control which provides a range spanning zero to full power. The value of VR1 is shunted by resistor R7 to counteract the wide tolerance typical of these controls. IC2 acts as a comparator and drives output transistor TR1 (a general-purpose *npn* medium power transistor), which in turn powers the brushless motor. Diode D1 counters any back-EMF that may be present.

The opamp used for IC2, e.g. the 3130 should have an output capable of reaching negative rail so that the transistor is turned completely off when it is low. No external compensating capacitor is necessary for the opamp in this switching application. Some other opamps which could be used in this position include the 3140, half an LM358 or perhaps one of the new generation of rail-to-rail CMOS types. (Also see our Opamp Selector Chart in *Circuit Surgery*, March 2000 – *ARW*.)

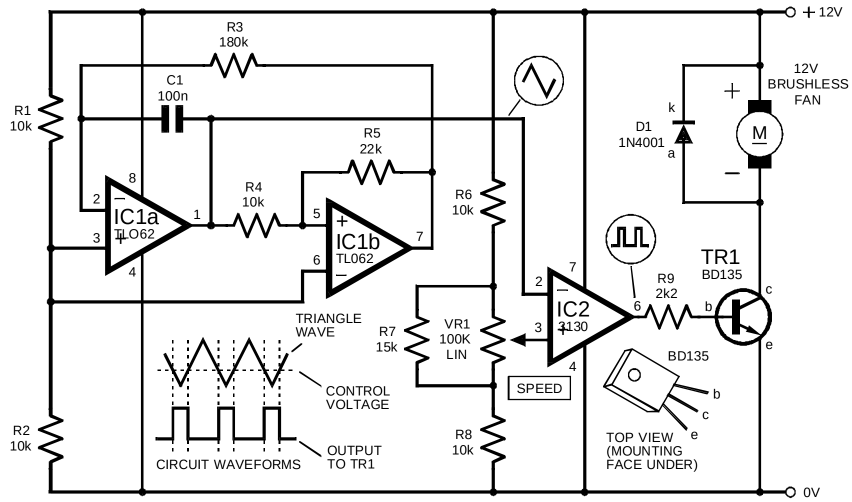


Fig.3. Circuit diagram for the Brushless Fan Speed Controller.

Motors used with this circuit should be 12V types. When tested, a 75mm fan from a scrapped 386 computer and a 47mm Pentium CPU fan both worked without any problems. The motors were surprisingly tolerant of high pulse rates, frequencies up to 100Hz being accepted with no performance loss. The larger fan produced some audio noise at higher frequencies, the smaller unit much less, and this could be minimized by adjusting the frequency through the values of R3 and C1. The values shown produce a frequency of about 33Hz for good performance and minimal noise. Experiment if necessary by attaching extra mass to the motor's armature to increase inertia, otherwise the rotation may be slightly jerky. A drop of dry lube oil on the bearing may also help.

Andy Flind
Taunton, Somerset, UK

Go to next section

HIGH PERFORMANCE REGENERATIVE RECEIVER by RAYMOND HAIGH

Provides continuous coverage from 130kHz to 30Mhz.

Last month we explored the merits, and problems, of regenerative receivers and gave an in-depth circuit description. We also included the component listing and offered the option of-"electronic tuning."

We conclude this month with the assembly, plug-in tuning coil details, and setting-up procedure.

CONSTRUCTION

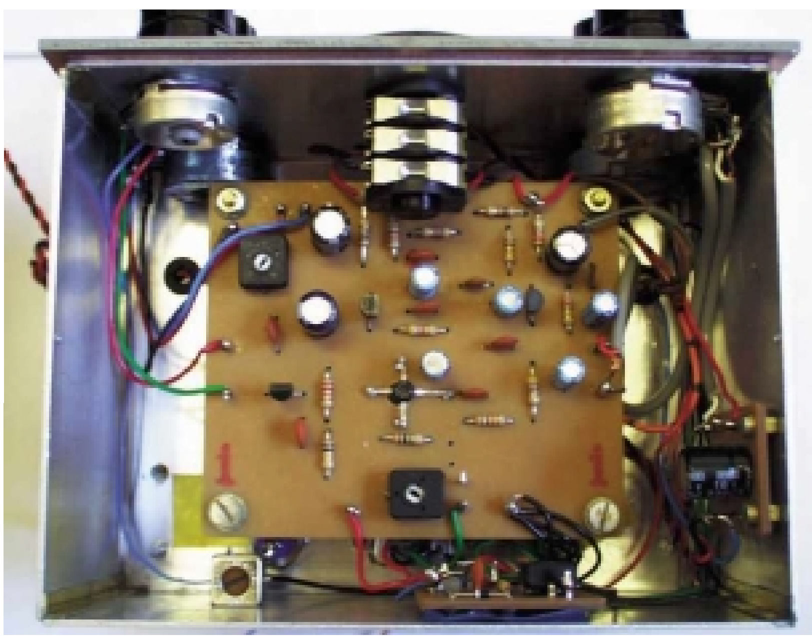
The receiver, power amplifier, and the alternative electronic tuning system are assembled on three small printed circuit boards (PCBs). This enables constructors to select what they want from the design and to use tuning components that may be to hand. Many will already have suitable audio amplifiers, and not everyone will wish to adopt electronic tuning.

The three printed circuit boards are available as a set from the *EPE Online Store* (codes 7000254, 7000255 and 7000256) at **www.epemag.com**. The topside component layout and (approximately) full-size copper track masters of the three PCBs are illustrated in Fig.4, Fig.5, and Fig.6.

Starting with the main Receiver board, mount the smallest components first, working up to the largest, but solder the semiconductors on to the board last. It is a wise precaution to clip a small heat shunt (such as a crocodile clip) to the leads of the field effect transistors (FETs) when they are being soldered.

Use solder pins, inserted through the board at the dual-gate MOSFET lead-outs, to enable it to be located on the component side. Solder pins

RF Attenuator VR1   *Headphone socket*   *AF Gain VR8*



Layout and wiring of the three PCBs, headphone socket, and under-chassis controls.

Audio power amplifier PCB.

Wave trap   *Electronic tuning PCB.*

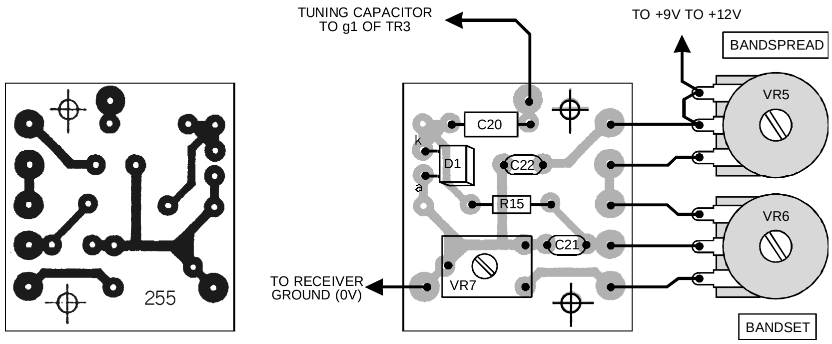
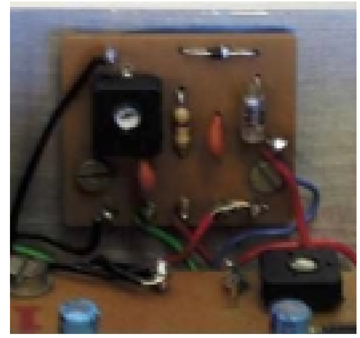


Fig.4. Printed circuit board layout for the electronic tuning system (approximately full size).



Tuning board mounted on the side of the chassis.

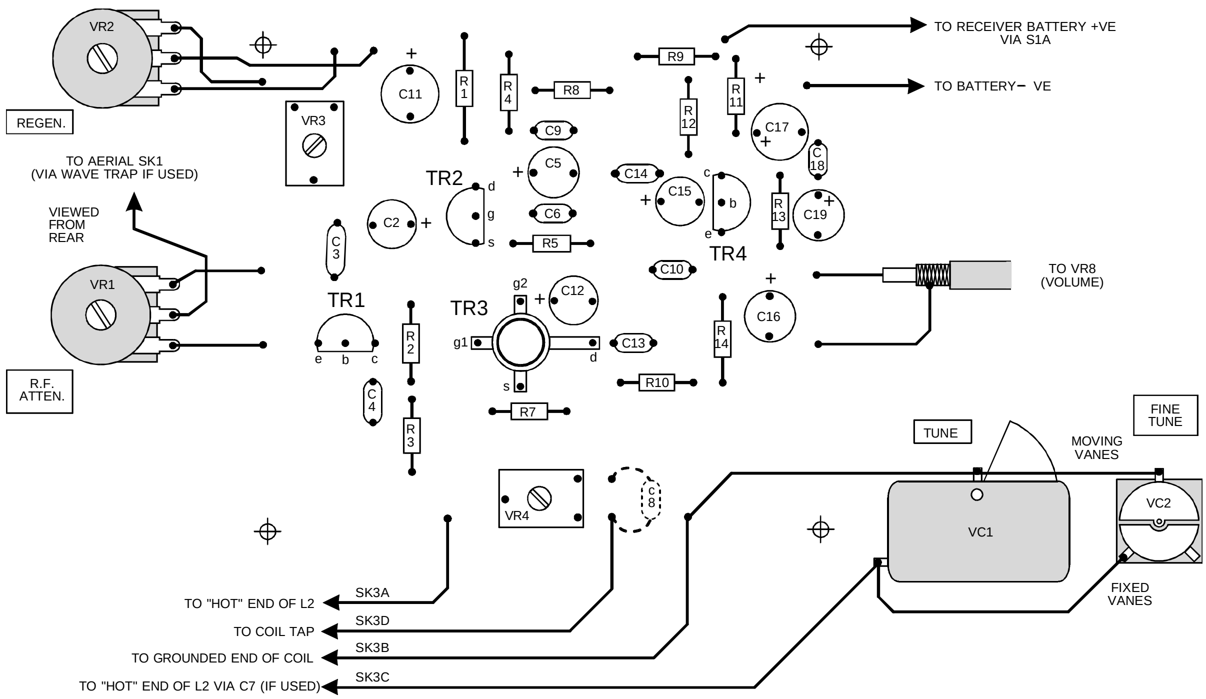


Fig.5. Main PCB layout and wiring and (below) approximately full-size copper foil master for this board.

Chassis topside layout showing D-type socket for the tuning coils.

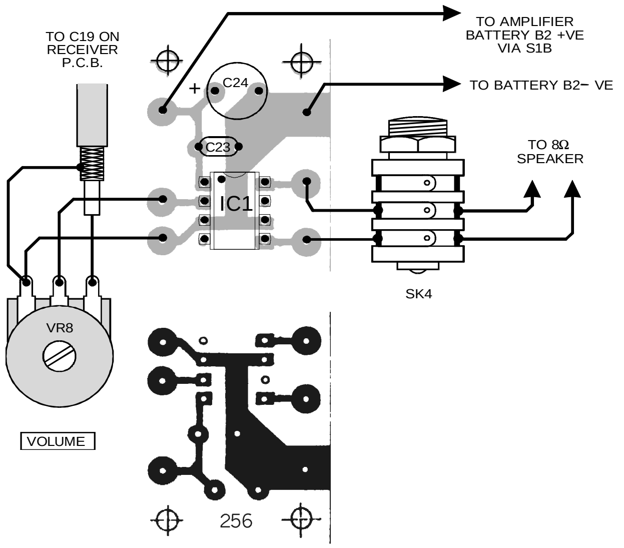
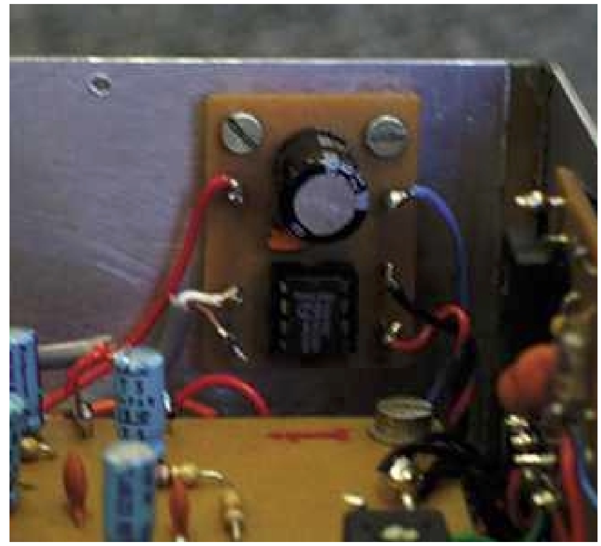


Fig.6. The audio power amplifier PCB (approximately full size).



The audio amplifier PCB mounted on the side

With care a neat construction for L2 can be achieved.

should also be inserted, just to the right of VR4, so that capacitor C8 can be temporarily soldered across preset VR4 during the setting up process.

Solder pins inserted at the PCB interwiring points will ease the task of off-board wiring. Use of an 8-pin DIL socket will facilitate the substitution and checking of IC1.

The same construction approach should be adopted for the two smaller boards.

Table 2: Tuning Ranges

TOKO Coils and a 10pF-365pF Variable Capacitor
(see Fig.7 for details of coil base wiring)

TOKO Coil	Base Wiring	C7 pF	R6 ohms	C8 pF	Min freq. MHz	Max freq. MHz
CAN1A350EK	C	--	12k	--	0.130	0.322
RWO6A7752EK	C	--	6k8	--	0.257	0.765
RWR331208NO	A	--	22k	1000	0.510	1.600
154FN8A6438EK	C	470	8k2	--	1.246	3.034
KANK3426R	A	470	12k	1000	2.143	5.100
KANK3337R	A	470	3k3	1000	4.900	11.970
MKXNAK3428R	A	220	8k2	1000	11.200	23.500
KXNK3767EK	B	47	12k	10	22.000	30.500

Notes:
(1) Adjustable cores permit wide variation in tuning range.
(2) The 470PF capacitor, C7, reduces the variable capacitor swing to 10pF-205pF: with the 220pF capacitor, the swing is 10pF-137pF; and , with a 47pF capacitor as C7, 8pF-40pF.
(3) The RW06A7752EK coil is useful for covering the I.f. end of the Medium Wave band.

BAND CHANGING

Tuning coils (L2) could be connected into circuit by means of miniature crocodile clips and short (50mm maximum) wire links. However, a much better arrangement is to wire them, together with C7, R6, and C8 (when used), to 9-pin D-type computer plugs to make up plug-in modules and to mount a matching socket on the Receiver frame (see photographs). How this can be achieved is shown in Fig.7. Also illustrated are the different methods of connecting the coil windings.

Various versions of L2 for full frequency coverage.

RECEIVER ASSEMBLY

Layout is not critical, but connections between the tuning components and the receiver PCB must be short and direct and signal input and output leads should be kept well separated.

For the satisfactory reception of weak, amateur, SSB transmissions (where correct tuning is extremely critical), the PCBs and tuning capacitors must be very rigidly mounted and screened in a metal box or case. The prototype is assembled in and on a small aluminum box with a piece of double-sided PCB forming a screened front panel.

The photographs show how this is done. The arrangement has proved quite satisfactory, but a heavier, diecast metal box would be preferable, if one is to hand.

Some form of reduction drive to the Bandset capacitor VC1 will make tuning easier, and dial calibrations can be marked on a piece of card stuck to the front panel.

SETTING UP

This is very much a switch-on-and-go receiver, and the setting up process only involves optimizing the feedback levels so that the Regen. control VR2 is smooth and effective over the full swing of the tuning capacitor on all coil ranges.

First, check the PCBs for any bridged tracks or poor joints. Check the orientation of the semiconductors and polarized capacitors.

Set VR3 to minimum and VR4 to maximum resistance. Connect the Medium Wave coil into circuit, wire in capacitor C8, connect an aerial, and switch on.

Turn up the RF attenuator (VR1) and AF gain (VR8), then advance regeneration control VR2. Transmissions should be picked up, loud and clear, around the dial.

With the tuning capacitor VC1 fully meshed, set preset VR4 to the highest possible resistance consistent with the Q-multiplier just oscillating when Regen. control VR2 is turned to maximum. Measure the resistance of VR4 and permanently wire a fixed resistor of the same value, R6, in series with the tapping on the coil.

Preset potentiometer VR3 determines the voltage across the regeneration control. Set it to the highest possible resistance consistent with effective regeneration being obtained on all ranges.

The optimum values of resistor R6, measured on the prototype receiver, are listed in Table 2. They may not hold good for all dual-gate MOSFETs, but they will certainly be a useful guide.

Tabulated values of swing-reducing capacitors (C7) relate to a 365pF variable capacitor. If a different component is used, they will need modifying. Indeed, if its maximum value is as low as 200pF, swing reducers will only be required on the two highest shortwave ranges.

Coil cores should be set to give continuous coverage. Varying the inductance causes slight changes in the optimum value of resistor R6, and this part of the procedure should be carried out before the resistors are selected.

OPERATION

Best results will be obtained by attenuating the RF input as much as possible and adjusting AF gain to ensure audibility.

The regeneration control VR2 should be set just short of the oscillation point when receiving broadcast transmissions. When amateur SSB signals are being tuned in, it must be advanced until the Q-multiplier stage is just oscillating. (The internally generated oscillation replaces the carrier removed at the transmitter so that the detector can render the signal intelligible in the usual way.)

If the set is reluctant to regenerate, strong signals tend to spread across the dial, or difficulty is encountered when trying to clarify SSB signals, reducing the input from the aerial will invariably cure the problem. In cases where local Medium Wave or, less likely, Long Wave transmitters swamp the receiver, a wave trap (L1/C1) will have to be fitted.

CALIBRATION

A crystal marker or signal generator can be used for calibration purposes. Alternatively, an "all-band" radio with an accurate dial (preferably digital) should prove suitable.

Take a short aerial wire from the calibrating receiver and place it close to the Q-multiplier whilst it is oscillating. This will enable the radio to pick up the radiated energy.

The two receivers can now be tuned in step whilst the dial is marked out. Even if the calibrating receiver does not have a BFO (beat frequency oscillator) to make the oscillations audible as a tone, the presence of the signal should be discernible.

Refer to Table 2 for guidance on the frequency coverage to be expected with individual coils. It is easy to be confused by harmonics whatever method of calibration is adopted.

PERFORMANCE

When correctly set up and operated, the radio is sensitive, selective, and capable of receiving broadcast and amateur transmissions from all over the world.

If a reasonable aerial is used, say 15 meters or 20 meters of wire located as high as possible and clear of earthed objects, the RF input control will have to be turned well down when listening to all but the weakest stations. An earth (a metal rod in the ground) connection can improve reception, especially at low frequencies.

The receiver has a clear, pleasant tone, and audio output is more than adequate.

Go to next section

New Technology Updates

IAN POOLE REPORTS THAT THE DEVELOPMENT OF ELECTRONIC INK MAY INDEED HELP TO ACHIEVE THAT ELUSIVE DREAM – THE PAPER-LESS OFFICE!

The paperless office is something that has been long talked about but has never happened. Rather than reducing the amount of paper that is produced, computers and computer technology appear to have had exactly the opposite effect, causing paper to be used in vastly greater quantities than before the computer revolution.

Using computers it is far easier to produce enormous quantities of paper. Multiple copies of a document can easily be printed out. Also looking at a document on screen is never there same as reading a hard copy. Proof checking and even looking at the document or picture to see whether it is right can all be done more easily when a hard copy is to hand.

There have been many attempts to introduce the paperless office. New facilities like email have been introduced and have helped in many ways, but initiatives like these often just seem to increase the amount of traffic traveling to and fro without reducing the actual amount of paper produced.

Many companies would like to reduce the amount of paper that is produced. Apart from important factors like green issues, paper documents and drawings are costly and take space to store. If they could be stored electronically and the impetus to print things onto a hard copy could be reduced then the paperless office might have a chance.

NEW IDEA

In an attempt to overcome this problem, a new idea know as electronic ink is being developed. A new company named ImmediaTM is developing a thin light weight display. Its format is such that it can almost be considered as

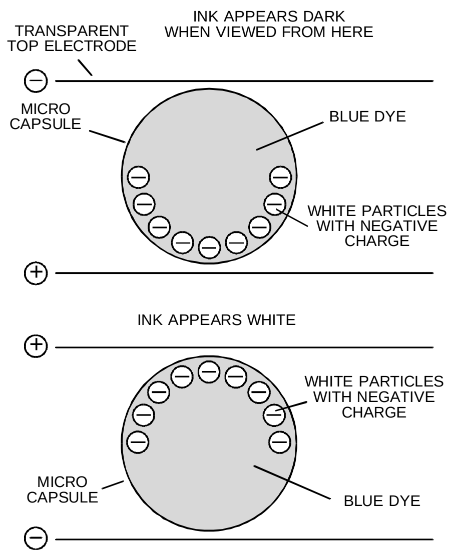


Fig.1. Operation of electronic ink.

paper on which messages can be displayed and changed electronically.

This gives an enormous scope for new methods of displaying information. Not only can it be used for emulating paper, but it can also be used in many other ways for displays on a variety of surfaces, as the technology does not have the limitations of cathode ray or liquid crystal technology where rigid constructions are needed.

The idea involves the use of two new and developing technologies. The first is the electronic ink itself, and the second is the carbon based organic transistors that are being developed by Lucent Technology's Bell Laboratories.

ELECTRONIC INK

The ink consists of millions of minute spheres. These are the key to the new technology, containing a dark dye and very small particles of titanium oxide suspended in a light oil. The titanium oxide pigments are white in color and carry a negative charge. Accordingly, under the influence of an electric field the oxide particles will either move to the back or front of the sphere. With the oxide particles at the back of the sphere, the dye is seen, and the area appears dark, but when the oxide particles are at the front of the sphere, the area appears white. In view of the size of the microcapsules, the definition of the display is governed by the control of the electric charge.

One of the advantages of paper is that it offers a very high degree of contrast providing a true black on white image, rather than the gray on gray provided by a liquid crystal display. A further advantage is that the electronic ink gives a very wide angle of view. This is one of the main disadvantages of liquid crystal displays.

Running from supplies between 10 and 100 volts, the displays consume very little power, as they operate by the attraction of charges and do not require current to flow. This will

be of particular interest to developers of battery-powered equipment. It is also found that once the control is removed the pattern remains in place, providing a non-volatile display – a facet that could be widely used to advantage.

FLEXIBLE TRANSISTORS

The charge required to control the ink capsules can be applied through transistors. However to enable the display to be made sufficiently thin, the new organic transistor technology being developed by Lucent will be used. These devices have the further advantage that they are also flexible, enabling the display to be printed onto a variety of surfaces and not be contained by a rigid mechanical environment like that of a cathode ray tube, or a liquid crystal display.

It is also anticipated that it will be possible to print the displays onto other surfaces using traditional printing technology. This would be a tremendous step forward, enabling electronic displays to be situated almost anywhere. This is achieved by suspending the microcapsules in traditional ink as the transport mechanism. It would then be possible to control the capsules.

The goal is to be able to print the transistors onto a flexible plastic film containing the microcapsules. The transistors will then be able to activate small areas (pixels) within the display area to create whatever shapes are required.

Development of both areas of the technology required for the display is still under way. Nevertheless a prototype display using traditional semiconductor technology has been put together and has shown encouraging results.

DEVELOPMENTS

Although the basic idea has been proven, there is still much development to be undertaken before displays in the final form are seen. Those developing the drive system using the new transistors are exploring the requirements for them. Decisions have to be made about the characteristics of the devices including whether they should be *p*-type or *n*-type.

Research is also progressing in the area of the electronic ink itself. One area they are investigating is various combinations of dye and white pigment. These too are crucial to the operation of the system.

Obviously the first aim is to move towards a small-scale demonstration of the system. It is hoped to build a display with about 100 pixels within the next year. This will demonstrate the performance of the whole system, and give information to enable the development to move on to the next stage.

Moving on from this, the first major goal will be to produce signs or paper that can be remotely updated. At this stage it may also be possible to produce low cost flexible displays for the many portable products that will be available. Ultimately the goal is to produce an electronic book, with pages that can be viewed in the same way that a traditional paper book can be viewed. Whether this becomes reality, or whether technology takes the development down a different road remains to be seen.

However, it is certainly an interesting development, and one that may have a significant effect on the format of electronic products and the man machine interface in the years to come. It may even help resolve the problem of the paperless office.

Go to next section

By Alan Winstanley

I'm all .sch.uk up

One of the first things to ponder when creating an Internet presence is what domain name to adopt, and it is here that many organizations may immediately face a difficulty: someone may already have beaten them to it, so they may be forced into using something less relevant (or memorable) instead.

The fact is that the demand for domain names has rocketed since the late 1990's. In effect, if you can think of a name, a word or a place then there is a good chance that the domain name has already been spoken for. However the practice of "cybersquatting" on a domain name is increasingly frowned upon, and there have been several celebrated cases of failed attempts to profit from a name, by trying to sell it to its rightful but less forward-thinking owner (e.g. **marksandspencer.co.uk**).

The laws of attempted passing-off and trademark infringement may also be invoked. In short, you cannot apply for your "own" domain name soon enough, if only to prevent competitors from beating you to it, so if you are contemplating creating an Internet presence now or in the future, then you should investigate this aspect with some urgency.

The issuing of the **.uk** top-level domain (TLD) name is controlled by Nominet (**www.nominet.org.uk**), and the cost of a dot-UK name has fallen dramatically to reflect the increased uptake. Second-level domains (SLDs) include **.co.uk** for commercial organizations, or if the names are registered at Companies House, **.plc.uk** for public limited companies and **.ltd.uk** for limited liability companies, together with **.sch.uk** for UK schools.

It is important to note that domains are issued on a first-come, first-served basis, and names are sometimes bought as a defensive measure to prevent them falling into the hands of other parties. A whole different set of rules relates to the popular dot com domains, and you should refer to Network Solutions at **www.networksolutions.com** if necessary.

Although it is easier than ever before to apply for a domain name, things can get rather complicated because there are several parties to the Nominet agreement. Firstly, there's you – the Registrant. The domain name is registered in your name (literally), so you gain the right to its exclusive use provided that Nominet's fees and terms are met. An Administrative Contact will be assigned, together with Billing and Technical Contacts; often these are the same. Using the Nominet WHOIS look-up (**www.nominet.org.uk/whois.html**), you can find out if **.uk** domain names are already taken. Also see **www.netnames.co.uk** to search for **.uk** and **.com names**.

The simplest way of acquiring a domain name is to ask an ISP to arrange it for you. Hopefully they will be members of Nominet, noting that the ISP acts as your agent only when completing the formalities on your behalf, using their credit account with Nominet.

You can also opt to buy your name directly from Nominet at a cost of 80 UK pounds + VAT for the first two years. The system is quite transparent as regards the registration costs, though, and Nominet members pay a heavily discounted price – only 5 UK pounds plus VAT for two years, although membership itself costs 500 UK pounds plus VAT to start with.

I'll name that domain in one

The market in web domains is now global, and on-line auctions such as those at **Amazon.co.uk** list names offered for sale for as much as $1,000,000. Some domain name and web design companies are doing a roaring trade in marketing domain names simply by cashing in on the ignorance of users in order to make a profit. One recent case involves an acquaintance working in the electronics industry who was approached by a dubious Internet company from the south of England. The representative phoned to say that somebody had recently tried to register my friend's company name as a domain and in order to prevent this happening again, he should register his name immediately. The Internet company *"could do this for him for a fee"* (surprise) and faxed through the application forms twice. I can imagine many inex-

perienced people falling for it.

Happily my friend suspected something fishy was going on. Clearly they were simply going through a directory of business names, picking out likely-looking sales leads and checking if a domain is already registered before phoning to drum up some trade. Beware of any such agreements, especially if they handicap your ability to move the name elsewhere. Most reputable ISPs will co-operate with each other if you decide to move, especially if they are ISPA members.

FREENETNAMES

In the event my colleague responded by getting his domain name for free instead! The Internet Service Provider Freenetname (**www.freenetname.co.uk**) adopts an altogether different approach. They will offer you your choice of domain name for free, along with 20MB of free web space and email as well. You must dial in via a local rate Freenetname dial-up account, which is how the offer is financed. A CD ROM is provided with pre-configured software.

This deal almost seems too good to be true, yet there appear to be no catches. Rather confusingly, Freenetname says in its FAQ that the domain is registered *"in the name of the person entered when the original Freenetname dialup account was created"* and later says that *"as long as the Freenetname Terms and Conditions... are upheld, the domain can continue to be used by the customer free of charge."*

However, if your account lapses (after 90 days or more of disuse), or if your Freenetname dialup account is terminated, then the domain name *"remains the property of Freenetname"* says the FAQ. At least you can choose to buy it outright from Freenetname for payment of a nominal fee, or transfer it to another firm. The whole situation regarding the rights to use a domain name can become very confusing, and it's worth looking around the Nominet site and also downloading their terms and conditions.

An associate is currently testing Freenetname and the dial-up bandwidth appears to be average and fairly uninspiring (as a 5MB download proved). However it beats paying a cold-calling salesman trying to cash in on your entitlement to a domain name.

Even English village names (15,000 of them) have been hoovered up and registered by the parochial portal builder Webhound Ltd. (**www.any-web.co.uk**). Judging by the defensive and indignant tone of their on-line FAQs (see **www.any-web.co.uk/Portal/Towns/Towns_FAQ.asp**),Webhound's shopping spree has had some stick and upset many prospective domain name users. The firm was forced to withdraw its original plan to sell a number of village domains to finance the rest of their portal-building project, saying that their site would ultimately be financed by paid-for advertising. They will also charge customers for the privilege of a domain-related email address. Their proposal to develop an entire portal at **www.ANY-Town.co.uk** containing a localized web content for 15,000 villages in Great Britain, seems an overly ambitious undertaking.

Webhound also aspires to build a genealogy portal site, and to facilitate this they claim unashamedly to have registered a large number of surnames as dot-com domains. Their web site declares that in their view *"surname domain names should be shared by all people of that name and not the lucky individual who registered it first."* Of course, this disingenuous ploy overlooks the fact that Webhound Ltd. was a "lucky" company which used exactly the same rules of first-come, first-served to grab all those surnames for itself in the first place. Perhaps the whole lot will be sold off one day in another Internet merger or takeover, village names and all. Winstanley dot com is already spoken for, by the way.

You can contact me by email to **alan@epemag.demon.co.uk**. My web site is at **http://homepages.tcp.co.uk/~alanwin**

Go to next section

A selection of ELECTRONIC CD-ROMS

Computer Desktop Encyclopedia

The award-winning source of computer terms, concepts, important products and interesting stuff!! An invaluable reference and an unmatched resource for anyone interested in computers. **($14.99 Special Offer! -- While Stocks Last!)**

The PhizzyB Computer Simulator

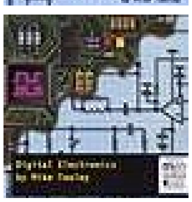
The *PhizzyB Simulator* provides an accurate representation of the real *PhizzyB*, including the ability to step and run through programs. Comes equipped with an assembler and other tools, plus user manuals (as PDF files on the CD ROM).

PICtutor by John Becker

This CD-ROM, together with the PICtutor development board (as described when you click on "more info"), will teach you how to use PIC microcontrollers. The board also acts as a development test bed and programmer for future projects.

Electronic Circuits & Components

This CD provides an introduction to the principles and application of the most common types of electronic components, and shows how they are used to form circuits. The CD also includes the "Parts Gallery".

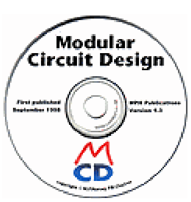


Digital Electronics (Mike Tooley)

This CD builds on the knowledge of logic gates covered on the Electronic Circuits and Components CD (described above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors

Analog Electronics (Mike Tooley)

This is a complete learning resource for the most difficult branch of electronics. The CD includes a host of virtual laboratories, animations, diagrams, photos, and text, as well as a SPICE electronic circuit simulator with over



Modular Circuit Design

This "web on a CD"-based educational software package contains essential information for anyone undertaking high school-level electronics or technology courses, and for hobbyists who want to get to grips with project design..

Visit the EPE Online Store at

www.epemag.com and place your order today!

Special Feature

Part 3 – Communications and Related Technologies 1900-1999

by Clive "Max" Maxfield and Alvin Brown

Boldly going behind the beyond, behind which no one has boldly gone behind, beyond, before!

The purpose of this series is to review how we came to be where we are day (technology-wise), and where we look like ending up tomorrow.

In Part 1 we cast our gaze into the depths of time to consider the state-of-the-art in electronics, communications, and computing leading up to 11:59pm on the 31st December 1899.

In Part 2 we discussed fundamental electronics between 1900 and 1999. Now, in Part 3 we consider some of the key discoveries in communications and related technologies that occurred during the 20th Century.

MIND BOGGLING!

When we originally set out to write this installment, we had thought it would be possible to describe a linear progression of developments, starting with the Morse Telegraph in 1837 and leading steadily onwards and upwards to the present day (we were young and foolish then).

For example, surely television was simply the next step after radio? Well not quite, because the first televisions were mechanical in nature, and used cable as a transmission medium.

In fact, the communications arena is a complete mish-mash of developments. Many core concepts were developed in isolation (the telephone and the radio, for example) and then brought together sometime later.

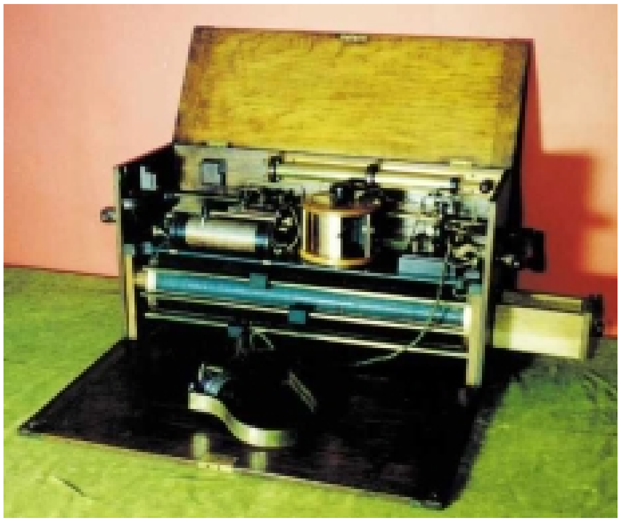
Similarly, communications media tend to come into favor, fall by the wayside, and then reappear with "go faster stripes". For example, copper telephone cables were displaced by radio waves and satellites, but now fiber-optic cables are proving to offer more efficient and cost-effective solutions in certain cases.

However, if we take a high-level view of communications over the last 100 years, four core technologies stand out as being particularly significant: the *telephone*, *radio*, *television*, and the *Internet*. There are also the key underlying delivery media, including cable (copper and fiber-optic) and radio transmissions.

Similarly, there are enabling technologies such as satellites and computers, along with off-shoot technologies such as microwaves (leading to radar and microwave ovens), radio astronomy, and … the list goes on. Thus, rather than attempting to artificially force everything into a linear progression, we are going to consider some of these core developments areas in whatever order we think makes sense!

EARLY RADIO

As the world entered the 20th Century, communication by means of radio waves was still only just beginning to emerge. Even though the telephone had been around for nearly 25 years, there was little thought given to



Crystal radio made by George Leadbetter, Worcestershire, 1910. This set is documented as having received Titanic's distress call on 15 April 1912. Courtesy National Vintage Communications Fair *(also see this month's News pages).*

using radio waves to communicate verbal messages, because the best that could be achieved was to transmit and receive individual pulses.

This meant that the first real use of radio as a communications mechanism was in the form of the Radio Telegraph, which was used to transmit messages in Morse Code.

During the early 1900s, Marconi's Radio Telegraphs were developed to the extent that they were installed on some ocean going vessels. However, these systems were mainly used to send commercial messages dubbed "Marconi Grams", and using them for such things as distress calls was not particularly high on anyone's priorities.

In fact, it was not until 1912 that governments started to mandate the installation of wireless equipment on ships following the sinking of the *Titanic*, whose radio operator sent out distress signals after the vessel collided with an iceberg.

DIODES AND TRIODES

Meanwhile, as far back as 1883, William Hammer (an engineer working for the American inventor Thomas Alva Edison) observed that he could detect electrons flowing from the lighted filament to a metal plate mounted inside an incandescent light bulb. This *Edison Effect* was subsequently used to create a vacuum tube rectifier by the English electrical engineer, John Ambrose Fleming in 1904 (this device was called a *diode* because it had two terminals).

Diodes were soon used in radio receivers to convert alternating current (AC) to direct current (DC), and also to detect radio frequency signals. Unfortunately, Fleming didn't fully appreciate the possibilities inherent in his device, and it was left to the American inventor Lee de Forest to take things to the next stage. In 1907, de Forest conceived the idea of placing an open-meshed grid between the cathode (the heated filament) and the positively biased anode (called the *plate*).

A Strowger automatic telephone of about 1905. Courtesy of Science Museum/ Science and Society Picture Library.

By applying a small voltage to the grid in his *Audion* tube (which became known as a *triode* because it had three terminals), de Forest could cause a much larger voltage change to be generated at the plate.

This was extremely significant for the fledgling radio industry, because it became possible to amplify radio signals captured by the antenna before passing them to the detector stage, which made it possible to use and detect much weaker signals over much larger distances than had previously been possible.

The triode was really rather cunning, but of equal significance was de Forest's 1912 discovery that he could cause his device to oscillate. This allowed him to replace existing spark transmitters with vacuum tube-based oscillators that could generate purer, more stable radio waves.

RADIO SET

One question that is often asked is *"Why is a radio commonly called a* radio set *or a* wireless set*?"* In fact, early radio systems intended for home use essentially consisted of three stages: the receiver (to detect and pre-amplify the signal), the demodulator (to extract the audio portion of the signal), and the main amplifier (to drive the loudspeaker).

All of these stages were packaged in their own cabinets, which had to be connected together. Hence the user had to purchase all three units, which formed a *set*, and this term persisted long after all of the components started to be integrated into a single unit.

In addition to requiring a mains supply to provide their high internal voltages, vacuum tube-based radios tended to be somewhat large, so the thought of a pocket radio didn't strike many people as being practical. However, the invention of the transistor in 1947 opened the floodgates for a whole raft of new applications.

In 1954, the Regency TR-1, the first pocket transistor radio,

was introduced in the USA. The Japanese transistor radio (TR-52) was produced, but not put on sale. It was the TR-55, which was the first *commercial* Japanese "tranny", introduced in 1955 by Sony. (SONY used to be called Tokyo Tsushin Kogyo Ltd in those now far-off days, but this didn't exactly roll off the tongue so you can see why they decided to change it).

THE TELEPHONE

Considering the fact that Alexander Graham Bell filed his patent for the first telephone in 1876, the actual development of this device has, in many ways, been remarkably slow compared to other consumer-orientated technologies. In the early days this was due to several reasons, not the least that there was no existing infrastructure (why have a phone if none of your friends have one and there is no one to call?).

By some strange quirk of fate, when an infrastructure eventually came along, it was so costly and huge that the technology had to migrate forward slowly. The fact that new systems had to work alongside old ones served to curtail revolutionary changes and to dictate an evolutionary adoption of new technology.

For example, it took British Telecom more than ten years to transition from electromechanical technology to its digital equivalent. Furthermore, these electromechanical switching exchanges, many of which persisted well into the 1990s, were themselves based on techniques that had been invented in America by Almon B. Strowger 100 years earlier.

AUTOMATIC SWITCHING

As fate would have it, Strowger was an unlikely character to have had such an impact on the development of telephone exchanges around the world. As an undertaker in Kansas City, USA, Strowger was an "early adopter" of telephone technology, because he thought it would facilitate potential customers (or at least their relatives) contacting him.

However, telephone exchanges in those days were manual, which meant that the person placing the call first contacted an operator, who then physically made the connection between the caller and the intended recipient.

As fate would have it, the operator who handled Strowger's calls was the wife of a competing undertaker. Thus, when potential clients tried to contact Strowger, she would instead connect them to her husband's business (the little rascal).

Not surprisingly Strowger found this state of affairs to be somewhat frustrating, so he set about designing an automatic system that would remove the operator (in the form of his competitor's wife) from the picture.

In fact, Strowger did not really invent the concept of automatic switching – Connolly and McTigthe had discussed the idea as early as 1879 – but with the help of his nephew (Walter S. Strowger) he was the first to come up with a practical implementation based on banks of electromechanical relay selectors in 1888.

In 1901, Joseph Harris licensed Strowger's selectors to

TIMELINES
1901: Marconi sends a radio signal across the Atlantic.
1902: US Navy installs radio telephones aboard ships.
1902: Transpacific cable links Canada and Australia.
1904: Telephone answering machine is invented.
1905: Dial telephone is invented.
1906: Dunwoody and Pickard build a crystal-and-cats-whisker radio.
1906: America. First radio program of voice and music is broadcast.
1907: Lee de Forest begins regular radio music broadcasts.
1909: Radio distress signal saves 1900 lives after ships collide.
1909: Marconi shares Nobel prize in physics for outstanding contribution made to telegraphy.
1910: America. First installation of teleprinters on postal lines between New York City and Boston.
1912: Titanic sends out radio distress signal when it collides with iceberg.
1912: Feedback and heterodyne systems usher in modern radio reception.
1914: Better triode valve improves radio reception.
1914: Radio message is sent from the ground to an airplane.
1914: First trans-continental telephone call.
1915: First transatlantic radio telephone conversation.
1916: Radios get tuners.
1917: Frank Conrad builds a radio station (becomes KDKA – call sign still in use to this day).
1917: Condensor microphone aids broadcast recording.
1918: First radio link between UK and Australia.
1919: People can dial their own telephone numbers.
1919: Shortwave radio is invented.

the Automatic Electric Co (AE). The first dial telephone was invented in 1905, and the combination of dial telephones and Strowger selectors paved the way for automatic telephone exchanges, such as the first public automatic telephone exchange in the UK, which opened in Epsom, Surrey in 1912.

Of course, Strowger exchanges were initially only used to process local calls – operator assistance was still required for long distance and international calls. In fact, it wasn't until 1971 that it became possible to direct-dial between the US and Europe!

TESTING, 1, 2, 3

With the advent of the triode valve in 1907 and the discovery of vacuum tube-based oscillators in 1912, it became apparent that speech could be transmitted by radio. The first significant demonstration of this concept occurred in 1915, when speech signals were successfully transmitted across the Atlantic between Arlington, Virginia, and Paris, France.

One year later, a ground-to-air radiotelephone message was transmitted from an airfield at Brooklands, England, to an aircraft flying overhead.

The first commercial radiotelephone service came into being in St Louis, Missouri, USA in 1946, but once again progress was somewhat slow due to the infrastructure and bureaucracy.

Following a number of attempts, the first mobile phone service started operating in North America in 1978. Across the Atlantic, the first cellular service was introduced in Europe in 1981 in the form of the Nordic mobile telephone system.

In fact, it is interesting to note that although America was the first to deploy a cellular service, the multiple competing standards in the USA have caused that market to become segmented and fragmented.

By comparison, Europe and Japan are now years ahead of the USA, because they were quick to adopt a common standard. For example, as of 1998 there were 100 million cell phone subscribers in Europe, with 5 million new subscribers joining each month.

QUOTABLE QUOTES

"The radio craze will die out in time", Thomas Edison, 1922

"While theoretically and technically television may be feasible, commercially and financially I consider it an impossibility", Lee de Forest, 1926

MECHANICAL TV

Ferguson Model 993T 14-inch console television, original invoice dated 29/5/54 for 75 pounds and 12 shillings.
Courtesy Dreweatt-Neate.

1921: Quartz crystal keeps radio from wandering.
1922: First commercials broadcast ($100 for 10 minute advert).
1922: Lewis Alan Hazeltine invents the neutrodyne which eliminates squeaks and howls of earlier radio receivers.
1923: First ship-to-ship communications (people on one ship can talk to people on another).
1925: First commercial picture/facsimile radio service across USA.
1926: First commercial picture/facsimile radio service across Atlantic.
1926: John Logie Baird demonstrates an electromechanical TV system.
1927: Philo Farnsworth assembles complete electronic TV system.
1927: First public demonstration of long-distance television transmission (basically a Nipkow disk).
1929: Experiments begin on electronic colour television.
1929: First ship-to-shore communications (passengers can call relatives at home – at a price).
1929: The first car radio is installed.
1929: In Germany, magnetic sound recording on plastic tape.
1929: British mechanical TVs roll off production lines
1933: Edwin Howard Armstrong conceives a new system for radio communication – wideband frequency modulation (FM).
1934: Half the homes in the USA have radios.
1935: Audio tape recordings go on sale.
1935: All-electronic VHF television comes out of the lab.
1935: England. First demonstration of radar, at Daventry.
1936: Munich Olympics televised.
1936: First electronic speech synthesis (vodar).
1937: Pulse-code modulation

Television, which comes from the Greek *tele*, meaning *distant* and the Latin *visio*, meaning *seeing* or *sight*, has arguably become one of the wonders of the 20th Century.

Prior to the advent of electronic scanning, all workable television systems depended on some form or variation of the mechanical sequential scanning method exemplified by the Nipkow disk (as discussed in Part 1).

Modern television systems are based on the cathode ray tube (CRT). The idea of using a cathode ray tube to display television images was proposed as early as 1905, but progress was hard fought for, and it wasn't until the latter half of the 1920s that the first rudimentary television systems based on cathode ray tubes became operational in the laboratory.

There are two primary requirements for a functional television system: a technique for capturing an image and a way to display it. Following Nipkow's experiments, other inventors tried to move things forward with limited success. The history books mention several names in this regard, such as John Logie Baird, a Scotsman who used a derivation of Nipkow's disks for capturing and displaying pictures during the latter half of the 1920s and the early 1930s.

The British Broadcasting Corporation (BBC) allowed Baird to transmit his pictures on their unused radio channels in the evening. By 1934, even though he could only transmit simple pictures with a aximum resolution of around 50 lines, Baird had sold thousands of his *Televisor* receivers around Europe in the form of do-it-yourself kits.

Meanwhile, on the other side of the Atlantic, the Radio Corporation of America (RCA) experimented with a system consisting of a mechanical disk camera combined with a cathode ray tube display. Using this system, RCA transmitted a picture of a model of Felix the Cat endlessly rotating on the turntable of a record player in the early 1930s.

PHILO FARNSWORTH

Strange as it may seem, relatively few reference sources seem to be aware of the real genius behind television as we know it today – an American farm boy named Philo T. Farnsworth from Rigby, Idaho. In 1922, at the age of 14, with virtually no knowledge of electronics, Philo conceived the idea for a fully electronic television system. Flushed with enthusiasm, he sketched his idea on a blackboard for his high school science teacher.

Over the years, Philo solved the problems that had thwarted other contenders. He invented a device called an Image Dissector, which was the forerunner to modern television cameras, and he also designed the circuitry to implement horizontal and vertical flyback blanking signals on his cathode ray tube, which solved the problems of ghosting images.

By the early 1930s, Philo could transmit moving pictures with resolutions of several hundred lines, and all subsequent televisions are directly descended from his original designs.

As video historian Paul Schatzkin told the authors: *"Many engineers and scientists contributed to the emergence of the television medium, but a careful examination of the*

points the way towards digital transmission.
1938: John Logie Baird demonstrates live TV in colour.
1938: Television broadcasts can be taped and edited.
1938: Radio drama War of the Worlds causes widespread panic.
1939: Regular TV broadcasts begin.
1939: Bell labs begin testing high-frequency radar.
1940: Bell labs conceive the idea of cell phone (technology won't exist to bring it to market for another 30 years).
1941: First touch-tone phone systems (too expensive for general use).
1941: First microwave transmissions.
1945: Sci-fi author Arthur C. Clark envisions geo-synchronous communications satellites.
1946: Automobile radiotelephones connect to the telephone network.
1948: America. Airplane rebroadcasts TV signal to nine States.
1949: America. Start of network TV.
1950: Vidicon camera tubes improve TV pictures.
1952: Sony demonstrates first Japanese miniature transistor radio (produces it commercially in 1955).
1953: America. First TV dinner is marketed by the C.A. Swanson company.
1954: Launch of giant balloon called Echo 1 – used to bounce telephone calls coast to coast.
1954: Number of radio sets in world out-numbers newspapers sold each day.
1956: First transatlantic telephone cable goes into operation.
1957: Russia launches Sputnik 1, the world's first artificial satellite.

record shows that no one really had a clue until Philo Farnsworth set up shop in San Francisco at the age of 20 and said: We'll do it this way!*".*

COLOUR TELEVISION

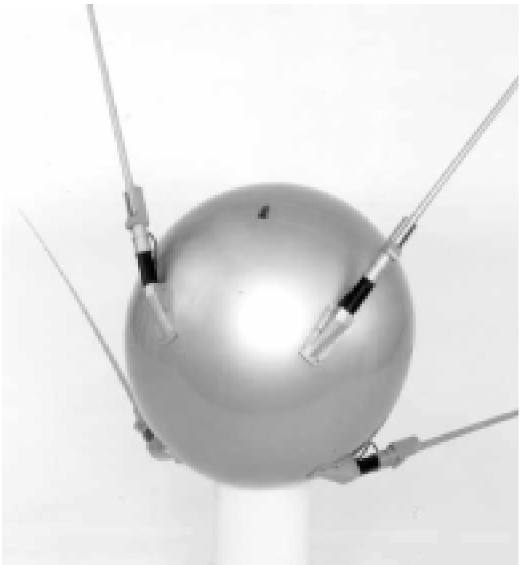
Perhaps the earliest proposal for color television is to be found in a German patent from as far back as 1904. However, it was not until 1928 that Baird gave the first practical demonstration of a color television using mechanical scanning based on a Nipkow disk having thee spirals of 30 apertures, one spiral for each primary color in sequence.

As we've already discussed, however, electronic techniques came to dominate the market, and creating color variations of these systems was significantly more problematic. One big problem was the number of black and white television sets that had already been deployed, because it was decided that any proposed color system had to be backwards compatible (that is, the color signal had to be capable of driving both color and black and white sets).

Public broadcasting of color television began in 1954 in the United States. Widespread adoption of color receivers in the United States followed in 1964, and in Great Britain and West Germany in 1967.

TELEVISION STANDARDS

Standards are great, everybody should have one, as the old saying goes.



Reconstruction of Sputnik 1, the world's first artificial satellite, launched 4 October 1957.
Courtesy Science Museum/Science and Society Picture Library.

Unfortunately the US settled on television pictures composed of 525 lines being refreshed at 30 frames per second, while Europe decided to use 625 lines at 25 frames per second. Other countries subsequently adopted one or the other of these standards (and don't get us talking about NTSC versus PAL, or the fact that the French decided to go their own way with SECAM).

UNDERSEA CABLES

As we discussed in Part 1, the first undersea telegraph cable was laid in 1845 between England and France. The Atlantic was spanned in 1858 between Ireland and Newfoundland, but the cable's insulation failed and it had to be abandoned. Following these early attempts, the first successful transatlantic telegraph cable was laid in 1866, and in the same year another cable, partially laid in 1865, was also completed.

1960: NASA and Bell Labs launch the first commercial communication

1962: America. Unimation introduces the first industrial robot.

1962: First commercial touch-tone phone systems.

1962: First commercial communications satellite (Telstar) launched and operational.

1963: Philips introduces first audio cassette.

1964: Birth of Practical Electronics magazine.

1967: Dolby eliminates audio hiss.

1967: America. Fairchild introduce an integrated circuit called the Micromosaic (the forerunner of the modern ASIC).

1968: America. First Static RAM IC reaches the market.

1969: First radio signals transmitted by man on the moon.

1970: America. Fairchild introduce the first 256-bit static RAM called the 4100.

1970: America. Intel announces the first 1024-bit dynamic RAM, called the 1103.

1970: Researchers at Corning Glass develop first commercial/feasible optical fiber.

1971: Birth of Everyday Electronics magazine.

1971: First direct telephone dialing between USA and Europe.

1971: America. Intel creates the first microprocessor, the 4004

1975: England. First liquid crystal displays (LCDs) are

1980: Faxes can be sent over regular phone lines.

1980: Cordless and cell phones are developed.

1989: Pacific fiber-optic link/ cable opens (supports 40,000 simultaneous conversations).

1992: PE and EE combine to become EPE.

1993: MOSAIC web browser becomes available.

These early attempts were plagued by deterioration of the signal over these huge distances and also by a lack of understanding of the environment 2,000 fathoms beneath the sea (could there be a film title here?).

Of course, the problems were significantly more daunting in the case of audio signals. In fact, these issues were not resolved until the invention of vacuum tube-based repeaters that could operate continuously and flawlessly with no attention for at least 20 years at these depths. These made possible the first transatlantic telephone cable, from Scotland to Newfoundland in 1956.

Following the success of this first cable, similar systems were deployed between California and Hawaii and between Hawaii and Japan in 1964. More recent undersea cables employ transistorized repeaters and provide even more voice circuits, and some are even capable of transmitting television pictures.

Today's cables, such as the Pacific cable laid in 1998, use technology based on fiber-optics and can handle 40,000 simultaneous conversations!

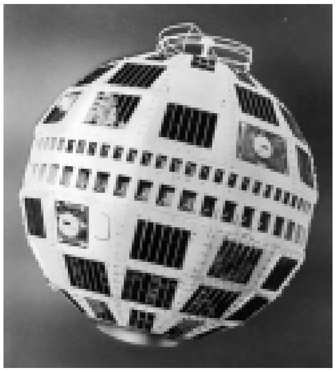
Echo 1, the first experimental communications satellite, during inflation tests. Courtesy Science Museum/Science and Society Picture Library.

SATELLITES

In 1952, the International Council of Scientific Unions stated that July 1957 to December 1958 would be the *International Geophysical Year* (IGY), because solar activity would be at a high point during this period. Two years later, in October 1954, the council adopted a resolution calling for artificial satellites to be launched during the IGY to map the Earth's surface.

In 1955, in a fit of exuberance, the American government announced plans to launch an Earth-orbiting satellite for the IGY, and set to work on the project. But much to their dismay, the (former) Soviet Union successfully launched *Sputnik 1*, the world's first artificial satellite on October 4, 1957.

Sputnik 1 was small (about the size of a basketball weighing in at 183 pounds, 83kg) and its sole function was to repeatedly beep a simple Morse Code-type message (to annoy the Americans). However, the significance of this event cannot be understated as it paved the way to a wide range of political, military, technological, and



Telstar 1, first commercial communications satellite. It was a multi-faceted sphere one meter in diameter. Courtesy of BT Archives.

scientific developments.

SPACE RACE

The Russian's ability to launch a satellite 50 times the mass of the American's proposed 3·5 pound (1·6kg) payload sent shivers of fear throughout the Western world. It was obvious to all that intercontinental ballistic missiles were now more than a possibility. Thus, in addition to causing the Americans to form NASA (which gave us Velcro fasteners and Teflon for our frying pans), *Sputnik 1* initiated the so-called "Space Race".

This culminated with America putting a man on the moon, but also led to deep space probes throughout the solar system, and drove electronic developments like miniaturization in the form of integrated circuits, more efficient solar cells, and others too numerous to mention.

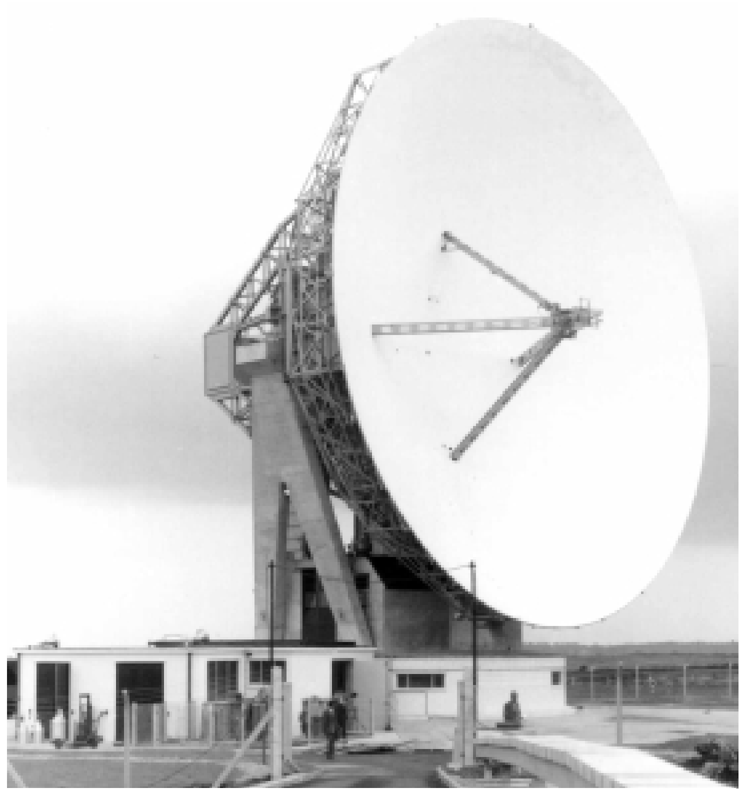
BALLOONS

Whilst working at Bell Laboratories in 1960, John Robinson Pierce developed the first experimental

communications satellite by bouncing radio signals of a 150-foot (45m) aluminum-coated high-altitude balloon called *Echo 1*.

These experiments were closely followed by the *Telstar* series of communications satellites, which initiated a new age in electronic communications. Unlike the passive reflection employed by *Echo 1, Telstar* received signals transmitted from a ground station, amplified them, and re-transmitted them to another ground station.

Following *Telstar's* launch on 10 July 1962, the first television pictures were transmitted across the Atlantic Ocean from a giant antenna near Andover, Maine, to a receiver located at Goonhilly in England. These television pictures were quickly followed by transmissions of telephone, telegraph, facsimile (FAX), and computer data.



Goonhilly Earth Station. Courtesy of BT Archives.

CRYSTAL BALLS

As far back as 1945, Arthur C. Clarke (who was to gain fame as a Science Fiction writer) proposed that microwave signals could be beamed to an unmanned orbiting satellite and bounced back to a different part of the world. But his key suggestion was that three satellites parked in a geo-synchronous orbit 36,000 kilometers above the Equator could be used to provide world-wide coverage. Clark's vision was eventually realized by *Telstar's* successors. Today, thousands of satellites race around the Earth, to the extent that it's becoming increasingly difficult to select an orbit for a new satellite so as to maintain a safe separation from existing devices.

RADAR

When Heinrich Hertz first began experimenting with radio waves in 1887, he discovered that they could be transmitted through some materials, but that they would be reflected by others. Almost 50 years later, scientists began to discover how to use radio waves to detect and locate objects.

In 1935, a report entitled *The Detection of Aircraft by Radio Methods* was presented to the British Air Ministry by Sir Robert Watson-Watt and his assistant Arnold Wilkins. This was soon followed by a trial, in which the BBC's short wave radio transmitter at Daventry, England was used to detect a British Heyford Bomber.

The success of this trial led to a chain of *Radio Detecting and Ranging* (RADAR) stations along the South and East coasts of England. These were to provide vital advance information that was to help the Royal Air Force win the Battle of Britain.

MAGNETRONS

Sad to relate, early RADAR sets were not as efficacious as one might have hoped for. What was required was a new generation of high and low power signal generators. One solution that was to find favor was the *magnetron*, which was developed by British physicists at the University of Birmingham in 1939.

A magnetron is a diode vacuum tube-like device that is capable of generating extremely high frequencies and also short bursts of very high power.

The need to manufacture tens of thousands of magnetron tubes to satisfy the war effort drove the British government to seek help from American industry. One company that was consulted was Raytheon, which already had been experimenting with their own microwave tubes.

After listening to the British

Original cavity magnetron, 1940. Developed by John Randall and Harry Boot of Birmingham University. Courtesy of Science Museum/Science and Society Picture Library.

scientists describe their method of producing the magnetron tubes, one of Raytheon's engineers, Percy L. Spencer boldly stated that their technique was "awkward and impractical". Percy took the tube home over the weekend and came up with radical changes that would both simplify the manufacturing process and improve the functioning of the radar.

Britain awarded the little-known Raytheon a contract to supply the magnetrons, and by the end of the war Raytheon was producing 80 percent of all magnetrons in the world. Spencer, a man with only a basic school education, became Raytheon's chief engineer.

MICROWAVE OVENS

The discovery of microwave cooking in 1945 is also attributed to Raytheon's Percy Spencer. A candy bar in Spencer's pocket began to melt as he stood in front of a magnetron tube that had been switched on. Spencer next placed popcorn kernels in front of the tube – and they popped.

Scientists already knew that magnetrons generated heat whilst radiating microwaves, but Spencer was the first to discover that one could cook food using microwave radio signals.

Based on Spencer's discovery, Raytheon demonstrated the first commercial microwave oven in 1947. These beasts were presented in refrigerator-sized cabinets and cost \$2000 to \$3000 (which was an expensive way to cook one's popcorn).

THE INTERNET

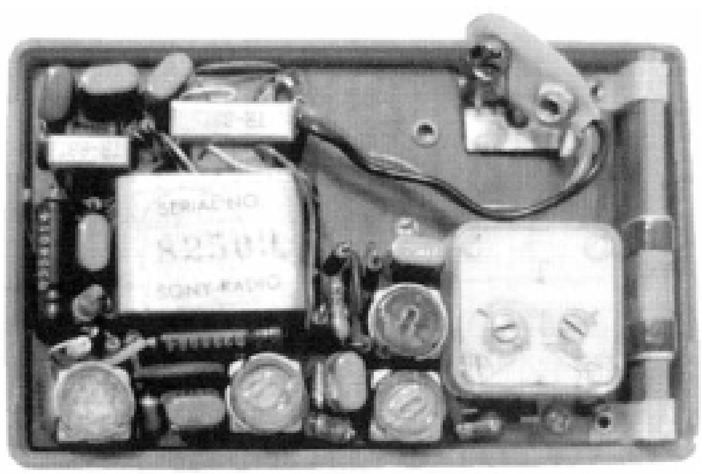
The latest development in the communications arena is the Internet, which combines the widespread availability of computers with every other communications technology known to man.

The Internet had its origin in a US Department of Defense program called ARPANET (Advanced Research Projects Agency Network), which was established in 1969 to provide a secure and survivable communications network for organizations engaged in defense-related research.

By the 1980s, ARPANET had evolved into a fledgling version of today's Internet that was predominantly used by academics as a way to publish textual data and as a text-based search engine.

One of the original uses of the Internet was electronic mail (commonly called e*mail*), bulletin boards and newsgroups, and remote computer access. The subsequent development of the World Wide Web (WWW), which enables simple and intuitive navigation of Internet sites through a graphical interface called a *Web Browser* (such as Netscape or Internet Explorer) was popularized by the release of the MOSAIC web browser in 1993.

In December 1999, the number of daily emails passed daily conventional mail letters for the first time.



Interior of a Sony TR-63 transistor radio. 114,536 of them were manufactured between March 1957 and November 1958. Courtesy Radio Bygones.

The Internet now uses radio, satellites, the telephone network, cable TV, amateur radio, and numerous other delivery media. In addition to raw computer data, the Internet is itself used to deliver static images, telephone conversations, music and television pictures. Cutting across national boundaries, the uncensored Internet is seen by many as being one of the most momentous achievements of the 20th Century.

The most amazing thing is that the Internet today is still in its infancy. In many respects, the state of the Internet at the beginning of the year 2000 is comparable to that of the telephone as the world entered the 1900s. However, the speed of the Internet's development is exponential compared to that of the telephone, and the social impact of the Internet will be more profound than most people can conceive.

NEXT MONTH

In Part 4 we shall turn our attention to computing in the 20th Century, and in Part 5 we shall polish up our crystal ball and peer into the future in a desperate attempt to predict the new and wonderful ideas and techniques that are racing towards us like a runaway train at the beginning of this new millennium!

Go to next section

InterFACE

ROBERT PENFOLD
Bidirectional Printer Ports

As regular readers will be aware, there have recently been changes to the way PC add-ons are tackled in this series of articles. Good old GW-BASIC and Q BASIC have been replaced by visual programming languages such as Visual BASIC 6.0 and Delphi 1 or 2.

Most projects now require a bidirectional printer port, whereas those featured in the past needed only a standard printer port. I think most would agree that these changes have resulted in projects that are superior to their predecessors, even though in most cases the hardware and software are actually simpler.

However, these changes seem to have caused an increase in the number of letters and emails relating to *Interface* articles. A number of projects that utilize a bidirectional printer port and (or) software written in a visual language will feature in future *Interface* articles, so it is perhaps worthwhile clarifying some points raised by readers before getting embroiled in these designs.

ONGOING

I think it is worth making the point that the *Interface* articles are largely self-contained, but they are also part of an ongoing series. It is a series that is not really aimed at beginners. When a design is featured in an *Interface* article, most of the information provided is specific to that project.

In general, background information is not provided. Some of this information is the type of thing that anyone having a reasonable amount of experience with computer add-ons should know. The rest is subject matter that has been covered in recent *Interface* articles.

In short articles of this type there is not enough space available to keep repeating things over and over again. If an article does not tell you everything you need to know it may be necessary to delve back a few issues for the answers.

BIDIRECTIONAL

One or two readers seem to have run into trouble because they have tried to use projects requiring a bidirectional port with old PCs that have standard printer ports. In general, Pentium PCs have bidirectional ports while 80486 and earlier PCs do not. However, some early Pentium PCs lack this facility and a few 80486 based PCs do have this bidirectional capability.

Some PCs that have bidirectional printer ports default to the standard mode of operation, and must be set to the bidirectional mode using the BIOS Setup program. The documentation supplied with the PC should give details of the BIOS Setup program and changing the mode of the printer port. It is SPP mode that is required, but EPP mode also seems to be suitable. ECP is an advanced mode that does not seem to support simple bidirectional operation.

The only sure way to determine whether or not a port can read data on its eight data lines is to run a simple test. Writing a value of 32 to the handshake output register sets a port to input operation, and data can then be read from the data lines at the base address of the port.

RIGHT ADDRESS

This brings us to another source of problems, which is determining the right address range for the printer port. There are three address ranges used for printer ports, as shown here:

Data Register	H/S Input Register	H/S Output Register
&H3BC	&H3BD	&H3BE
&H378	&H379	&H37A
&H278	&H279	&H27A

Most PCs have one printer port as standard, and this is usually at a base address of &H378, but some seem to use &H3BC. Where there is more than one printer port, the operating system designates the port at the highest address port one, the one at the next highest address port two, and if there are three ports, the one at the lowest address will be port three. If there are ports at addresses &H378 and &H278 for example, these will respectively be used as ports one and two by the operating system.

If you do not know the addresses of the ports in your PC the easiest way to find out is to use the Windows 95/98 System Information program. Operating the Windows Start button and then selecting Programs, Acces-

sories, System Tools, and System Information will launch this program.

Double click on Resources and then on I/O to bring up a list of the input/output address assignments. This will provide a list of the type shown in Fig.1, which should include the serial and parallel ports.

SIMPLE TEST

A very simple test routine is all that is needed to check whether the port supports bidirectional operation. This GW BASIC program will do the job. The addresses are correct for what will normally be printer port two, but they are easily changed if necessary.

```
10 CLS
20 OUT &H27A,32
30 LOCATE 10,20
40 PRINT INP(&H278)
50 GOTO 10
```

Line 20 sets the port to the input mode, and a loop then repeatedly reads the data lines and prints the results at the same point on the screen. Feeding various logic patterns to the data inputs of the port (pins 2 to 9) should produce the appropriate readings on the screen.

It is best to drive the port via current limiting resistors of about 220 ohms in value. If the port is still working as an output type these resistors will limit the current flow to a level that will prevent anything from being damaged.

ON THE CARDS

If the readings from the port do not change, it is clearly not a bidirectional type. The easiest solution is to fit the PC with a printer port card (see Fig.2) and any modern card of this type should support simple bidirectional operation. A card of this type should cost about 10 to 20 UK pounds from any large computer store, which is not bad for a port that provides a total of 17 input and output lines.

Since most PCs have a printer connected to parallel port one, adding a second port specifically for use with your add-ons is a good idea anyway. Assuming the existing port is at a base address of &H3BC or &H378, the new port should be configured for a base address of &H278, to use IRQ5, and for EPP or SPP operation.

DELPHI

Using visual languages with your own add-on devices is not as straightforward as using a traditional BASIC such as GW BASIC. Direct accessing of ports is permitted under Windows 95 and 98, but there is little support for doing this with Windows programming languages.

Borland's Delphi (a sort of visual Pascal) does have a Port function that can be used to read from and write to ports. However, this facility is only supported by version One of the program, and is absent from all the subsequent versions. The software for most user add-ons is fairly basic, and Delphi 1.0 is more than adequate for this type of thing.

Although it is no longer available as a separate entity, it is supplied with later versions of Delphi (both the commercial versions and the "free" versions occasionally given away with computer magazines). The original Delphi language produces programs that will run under Windows 3.1, but later releases are strictly for use with the 32-bit versions of Windows. Version 1.0 of Delphi is therefore included with later versions to provide 16-bit compatibility. Delphi 1.0 programs will run properly under Windows 95 and 98 incidentally.

Delphi 1.0 has definite advantages over the alternatives, and will probably be used to produce the programs featured in future *Interface* articles. One advantage is that it produces stand-alone programs that do

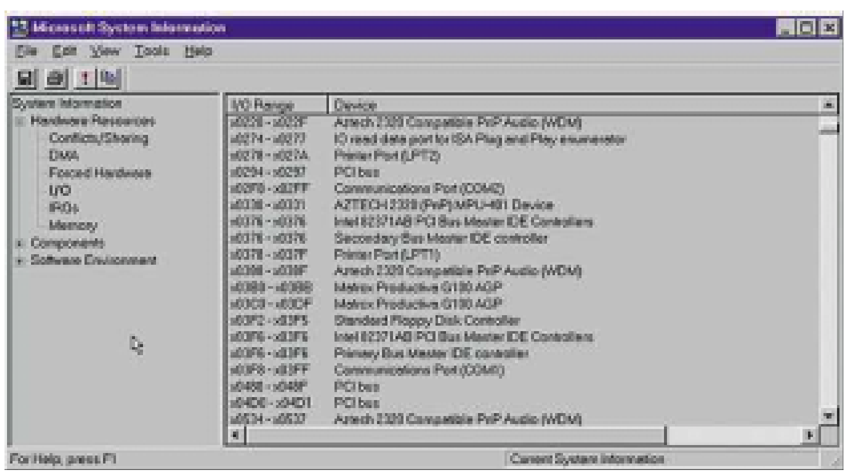


Fig. 1. The Windows System Information program can provide a list of address ranges for the hardware.

not have to be installed, and at around 200k to 250k they are not particularly big either.

As explained previously, Delphi 1.0 programs will run under Windows 3.1, 95, and 98. Because of the built-in Port function it is not necessary to resort to any software add-ons, keeping things simple and straightforward.

GETTING IN-LINE

Although Delphi 2.0 and beyond do not have a Port function they are equipped with a simple but effective in-line assembler. Reading from and writing to ports can therefore be accomplished using a few lines of assembler.

Due to the lack of a Port function it is not possible to compile any Delphi 1.0 listings provided in *Interface* articles using Delphi 2.0 or later. However, it should be possible to rewrite them to use assembler routines instead of the Port function, and the programs should then compile successfully under the 32-bit versions of Delphi.

As far as I am aware, the "free" versions of Delphi are not available for download at any web site. The size of these programs is such that it would take a very long time to download them anyway.

Versions up to Delphi 3.0 Professional have appeared from time to time as freebies on magazine cover discs. These are the same as the full commercial equivalents, but they are for personal use only. In other words, if you start to distribute your programs commercially you must buy "the real thing".

Programming user add-ons using Delphi 1.0 was covered in the June '99 issue of *EPE Online*, and using the assembler in later versions was covered briefly in the August '99 issue.

GOING VISUAL

Visual BASIC is now the most popular programming language, and it is probably the most simple to use. In recent years I have received a steady flow of enquiries about using this language with PC projects.

Unfortunately, as far as I can ascertain there are no INP or OUT functions in Visual BASIC 6.0 or any of the earlier versions. Neither is there a built-in assembler or any other integral function that provides access to the ports.

It is possible to access the ports using this language, but only with the aid of a software add-on. Anyone interested in using Visual BASIC with user add-ons should certainly pay a visit to the web site at **http://www.lvr.com** where there is a lot of information, software add-ons, and links to other useful sites.

If nothing more than basic port access is needed, and this is certainly all that is needed for most projects, the freeware DLL called ***inpout32.dll*** would seem to be the best option. Use ***inpout16.dll*** for 16-bit versions of Visual BASIC. Using either of these adds INP and OUT functions to Visual BASIC, and these functions are used in exactly the same way as their GW BASIC counterparts.

One or two readers have queried whether or not this file will be included when a program is compiled. Visual BASIC does not compile programs into standalone files, but instead produces a group of files complete with an install/uninstall program. A DLL file such as ***inpout32.dll*** will be included with the program group, and the installed program will function properly. Unfortunately, the smallest of Visual BASIC programs seems to compile into almost two megabytes of files!

WORKING MODEL

There is a "working model" version of Visual BASIC 6, but this does not seem to be available as a download from the Microsoft web site. Again, it would

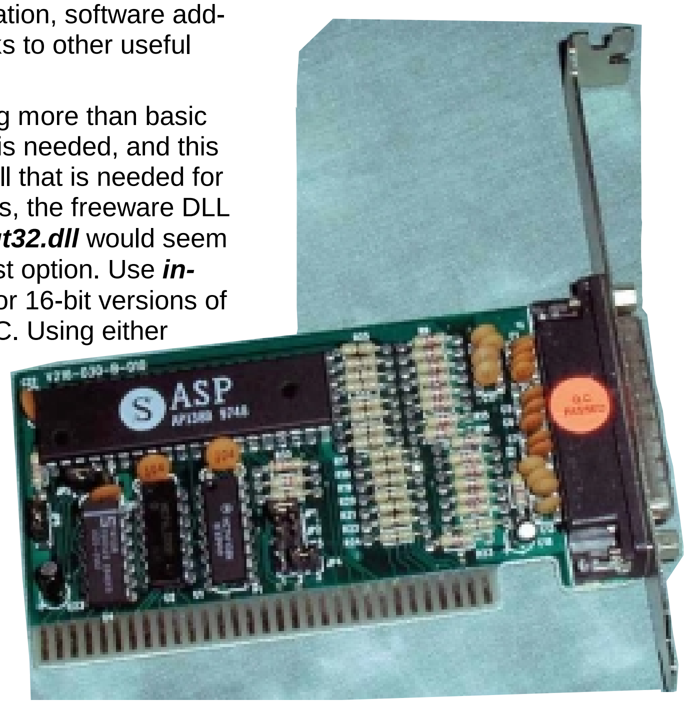


Fig. 2. A bidirectional printer port card.

probably take too long to download anyway.

The working model is almost the complete program, but it cannot compile programs. They can be run from within Visual BASIC though, rather like running programs under GW BASIC or Q BASIC. When run in this way the programs seem to run at full speed and without any restrictions.

The usual way of obtaining the Visual BASIC working model is to buy a book that includes it on the accompanying "free" CD-ROM. Although I hate to admit it, I found *"The Complete Idiot's Guide To Visual BASIC 6"* by Clayton Walnum (ISBN 0-7897-1812-X) an excellent introduction to Visual BASIC programming.

At around 15 uk pounds, complete with the working model version of the program, it probably represents the cheapest way of trying Visual BASIC 6. Using Visual BASIC with user add-ons was covered in the August '99 issue of *EPE Online* incidentally.

WINDOWS NT4

Windows 3.1, 95, and 98 all permit direct accessing of the ports, but Windows NT4 does not. It is designed to be more secure than other versions of Windows, and it only permits port accesses via the operating system. This ensures that two programs cannot simultaneously attempt to access the same piece of hardware.

There are add-ons that can provide programming languages with a port access facility in Windows NT4 (see the **lvr.com** web site mentioned earlier), but this is doing things the hard way. Windows 95 and 98 are a better choice for a PC that will be used with PC based projects.

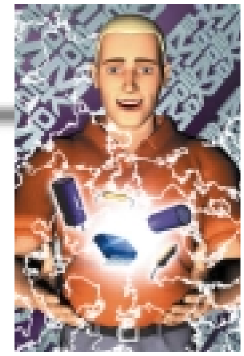
LIBERTY BASIC

It is perhaps worth mentioning a little known BASIC programming language called Liberty BASIC. This shareware program is a traditional BASIC that will produce Windows programs, and it includes INP and OUT functions.

Being shareware, this program can be tried out for the cost of downloading it from one of the source web sites. There are several of these including **http://www.liberty-basic.com**

Go to next section

TEACH-IN 2000



PART 6 – Logic Gates, Binary, and Hex Logic *by John Becker*

So we now have five parts of *Teach-In* 2000 under our belts and we know that you are greatly enjoying and learning from this 10-part series. We are pleased to have been told on many occasions that you appreciate the way in which we are leading you by the hand, on the assumption that you knew little or nothing about electronics before you started reading the series. Your complementary comments are very welcome.

We have covered the basic "passive" components and provided you with a means by which to create waveforms and display them on a PC-compatible computer screen. This enables us to now explore somewhat more sophisticated components of an "active" nature. Our experimental subjects this month are not only gates but binary counters to complement the Tutorial, and a decimal counter – for fun as well as instruction!

In previous parts of *Teach-In*, the term AND has been used from time-to-time. Indeed, in Part 4 we gave a brief description of what it does. The term occurs in both computing and electronics. In both instances, the implementation of AND is physically carried out by an electronic device or circuit somewhere in the system.

We explained that if two logic bits are ANDed together then the result will be logic 1 only if both source bits are also at logic 1. If either or both bits are at logic 0, the result will also be logic 0.

AND NOW THE GATES

The first subject to be covered this month is the expansion of the AND concept, and to describe not only integrated devices that use AND, but those that use the other five main logic functions, NAND, OR, NOR, XOR and XNOR.

One of the uses for an AND gate is as a signal (data) switch, only allowing the signal on one input to pass to the output if the other input is high. Another is to indicate whether or not all inputs are high, allowing, for example, a process to start if several preceding processes have been completed.

Let's use your breadboard and the oscillator you were using last month, plus an electronic AND gate, to demonstrate the AND principle, and in doing so to show its use as a signal switch.

The symbol for a 2-input AND gate is given at the top of Fig.6.1a (the table below it will be discussed presently).

From your bag of components, select a 74HC08 integrated circuit (IC). This IC is another digital electronic device (as are the 74HC04 and 74HC14 inverters you have already been using). It is a quad 2-input AND gate, and as such has four separate AND gate circuits within it. Its pinouts are shown in Fig.6.2.

Whereas the inverters each had one input and one output, the AND gate we are about to use has two inputs (as stated in its functional title) and one output. The logic levels applied to the two inputs can be regarded as the bits to which we referred a few paragraphs earlier when stating what AND means in an electronic or computing context.

It is worth noting that there are other AND gates which have more than two inputs. We shall not discuss them, but just comment that similar principles apply to all types. There are also other quad 2-input AND gates with different type numbers (indeed all the devices we use in this Tutorial are available with different type numbers to those quoted, but not necessarily with the same pinouts).

PRELIMINARIES

Before you remove the 74HC08 from its packaging, briefly touch something that is earthed to discharge any static electricity from your body. (See also Panel 6.1.)

Plug the IC (call it IC3) into your breadboard and connect it up as shown in Fig.6.3. Ensure

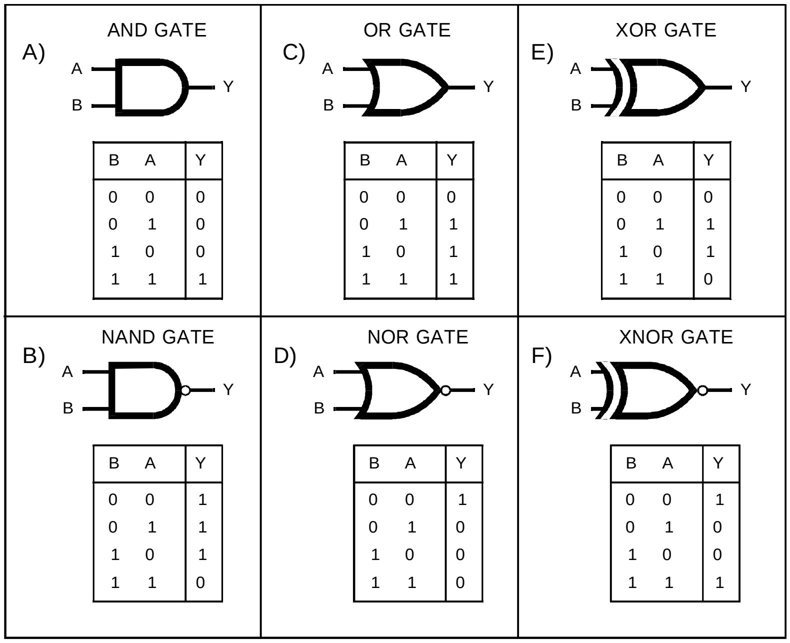


Fig.6.1. Symbols and truth tables for the six 2-input logic gate functions.

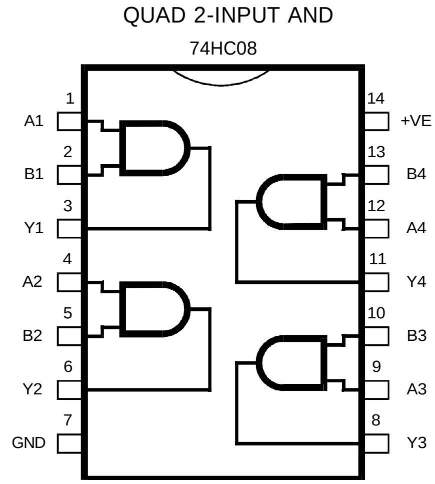


Fig.6.2. Pinouts for a 74HC08 2-input AND gate.

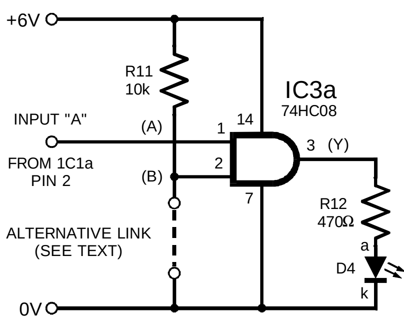


Fig.6.4. Circuit diagram for the AND gate experiment. The circuits for the other gates are similar.

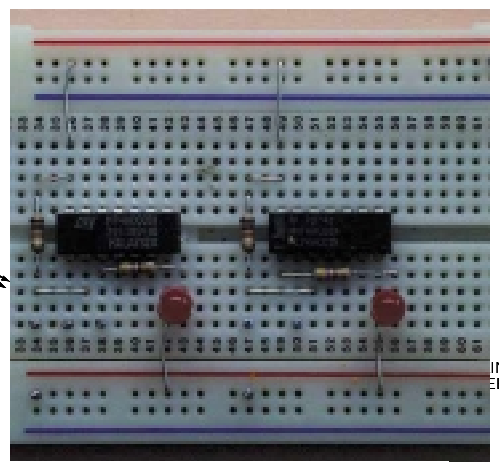


Photo 6.1. Breadboard showing the 74HC00 and 74HC02 configured for the demos. Note that they are not in the final recommended board positions.

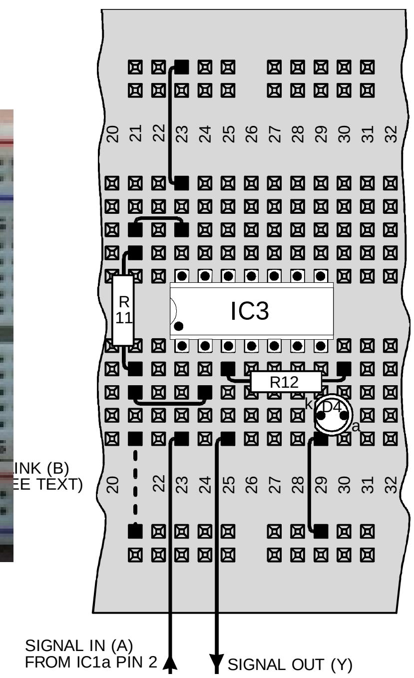


Fig.6.3. Breadboard layout for the AND, NAND, OR and XOR 2-input gate experiments.

that it is placed in the correct way round (as we discussed in Part 2).

We are using just one AND gate from within IC3, and shall refer to it as IC3a. Pin 1 (call it Input A) of IC3a connects back to the output of oscillator IC1a pin 2 (see Part 4). Pin 2 (Input B) of IC3a is linked to the positive power line via resistor R11.

The power line connections for IC3 are positive to pin 14 and 0V to pin 7. With the breadboard links as shown, these connections are automatically made to the battery when it is connected to the board as in previous experiments.

A LED (D4) is connected to the output of IC3a (pin 3) via the usual ballast resistor (R12).

The circuit diagram for this set up is shown in Fig.6.4.

Capacitor C1 of the oscillator should be 100uF.

Incidentally, the A and B names given to the gate inputs do not have to be in that order, or even with those names. They could even be called Input *John* and Input *Gill* if you wanted to. Nor is it necessary to use the same suffix letters as those

used here, the gate having pins 1, 2 and 3 could be named IC3d in another circuit (or even IC54c). It is entirely up to the circuit designer to give ICs whatever circuit part numbers he or she prefers.

FIRST TEST

Connect power to the board and adjust preset VR1 (Fig.4.1 in Part 4) until the oscillator's LED (D1) flashes on and off at a fairly even and slow rate. You should see that LED D4 also flashes on and off in time with D1.

Now make a temporary link between IC3a pin 2 (Input B) and the 0V power line (see Fig.6.3 – Link B). Leave R11 in place – it prevents the input from "floating", a condition in which the gate would be unsure of what logic state is on that input should you remove and swap a link wire between it and either of the power lines.

You will now find that LED D1 continues to flash, but LED D4 is turned off. Remove the link and D4 should flash again. This is what's happening:

In the first instance, the data (bit) at Input A (pin 1) of the AND gate has been set to logic 1 via the 10kΩ resistor R11. The data (bit) for Input B (pin 2) is alternating between logic 1 and logic 0, as provided by the oscillator. As we said before, the conditions in which an AND gate will produce an output of logic 1 is when both ANDed bits are at logic 1.

In the circuit you are running, one bit (A) is already at logic 1 (via R11), and the other bit (B) is switching between the two logic states. When bit B is at logic 1, the AND condition has been met and the output goes high, to turn on LED D4. With bit B low, the condition is not met and so the output is low, and D4 is off.

When you take bit A low by connecting Input A to 0V, the AND condition can never be met, irrespective of what happens on Input B. Thus LED D4 remains off.

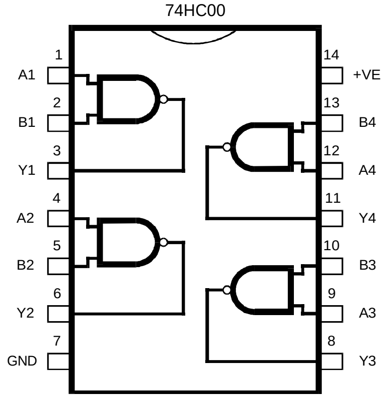


Fig.6.5. Pinouts for the 74HC00 quad 2-input NAND gate.

TRUTH OF THE MATTER

As you will have deduced, there is a permutation of four logic states that can occur on the two inputs of the AND gate. There is only one combination of those input states in which the output can go high. This permutation of states and their resultant outputs can be tabulated, as in Fig.6.1a, below the gate's logic symbol. Tables such as this are called Truth Tables.

The truth table in Fig.6.1a (and in those we give later and in the computer program) is headed with the inputs in order of B and A, which allows the table to be arranged so that the logic on these inputs is shown in binary value order (discussed later in this Tutorial). The output is headed with a Y (a common letter encountered with many, but not all, output-indicating illustrations and tables).

Truth tables can be compiled for any number of inputs and outputs of any digital logic device. Some can become very long indeed! For example, AND gates (and other members of the logic family) can have three, four, eight or even more inputs. The number of permutations of 2-state (digital) logic on those inputs is two to the power of the input quantity, e.g.:

INPUTS	PERMUTATIONS
1	$2^1 = 2$
2	$2^2 = 4$
3	$2^3 = 8$
4	$2^4 = 16$
5	$2^5 = 32$
6	$2^6 = 64$
7	$2^7 = 128$
8	$2^8 = 256$

NAND GATE LOGIC

We stated earlier that as well as AND gates, other types of gate exist to meet other logical conditions. The repertoire comprises AND, NAND, OR, NOR, XOR, XNOR, NOT (another term for inverter). Having met AND and NOT (the 74HC04 and 74HC14 inverters you've been using in the oscillators), we shall now discuss the others in turn, starting with the NAND gate.

The term NAND simply means NOT-AND. A NAND gate is thus an AND gate whose output is inverted. Its logic symbol and truth table are shown in Fig.6.1b.

The symbol is almost identical to that for the AND gate, except that the output has a small circle on it. This symbol is frequently encountered on outputs (and inputs) to signify that the logic is inverted.

You can, in fact, achieve a NAND situation by taking the output of an AND gate through

an inverter (try it sometime). There are, though, logic devices manufactured to specifically perform the NAND function. One such is the 74HC00.

The 74HC00 is a quad 2-input NAND gate, and its pinouts are shown in Fig.6.5. Note that the order of the pins per gate is identical to that for the 74HC08 AND gate.

With the breadboard power off, remove the 74HC08 and in its place put a 74HC00. Again touch something that is earthed immediately prior to handling it (as we advise you in Panel 6.1).

With power on again, do the same tests as you did with the 74HC08, connecting Input A (pin 1) variously between +VE (via R11) and 0V. Note the way in which LED D4 flashes compared with LED D1.

You should find that D4 will only be turned off when inputs A and B are both at logic 1, the opposite of the situation with the AND gate. Indeed, your findings should correspond to the data shown in the NAND gate truth table in Fig.6.1b.

OR GATE LOGIC

With a 2-input OR gate, the output is high if either Input A OR Input B is high. If neither is high, the output will be low. As with the AND and NAND gates, OR gates are available with more than two inputs. In these cases if any of the inputs are high, so too will be the output.

OR gates allow, for example, a process to start or continue if any preceding processes have been completed or are still in progress.

The logic symbol and truth table for a 2-input OR gate are shown in Fig.6.1c.

An example of a quad 2-

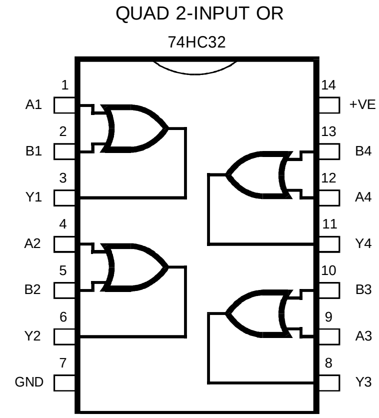


Fig.6.6. Pinouts for the 74HC32.

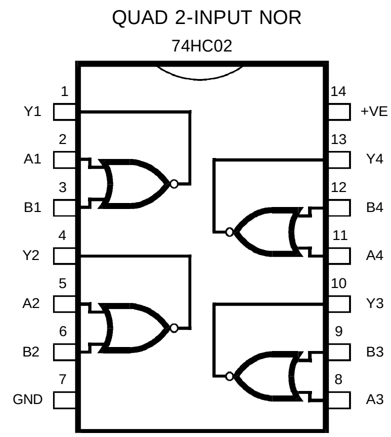


Fig.6.7. Pinouts for the 74HC02. Note that the pin order is different to the other gates discussed.

input OR gate is the 74HC32. Put one into your breadboard in place of the 74HC00. The pinouts are identical to the previous two gates.

Do the same tests as you did before, and compare your results with the truth table.

NOR GATE LOGIC

For a given input combination, a NOR (NOT-OR) gate produces an inverted output compared to that for an OR gate. The symbol and truth table for a 2-input NOR gate are shown in Fig.6.1d. Again note the inversion circle on the output.

Whilst NOR gates are available with several inputs, it is one of the quad 2-input types we use now, the 74HC02. Its pinouts are shown in Fig.6.7. Note that its pinouts are different per gate section to the previous gates.

The reason for this difference is unknown – it seems illogical. It has to be said, though, that there are occasional inconsistencies between what one might expect of a digital IC compared to what the situation actually is.

One reason given to the author many years ago is that digital logic devices were originally designed for the United States Military and that this had an affect upon how devices were manufactured.

Insert a 74HC02 into the breadboard in place of the previous OR gate, but connect it, plus the resistor and LED, according to Fig.6.8. Do your tests in the same way as before.

XOR GATE LOGIC

The term XOR stands for Exclusive-OR and such gates are only likely to be encountered as 2-input types. The logic symbol and truth table are given in Fig.6.1e.

The important thing to note about an XOR gate is that the output only goes high if the two inputs do not have equal logic values on them. If the inputs do have equal logic, then the output will be low.

This condition is highly useful in many situations, such as when you need to compare whether or not signals from two sources have equal logic values. The principle in computing allows easy assessment for the equality between byte values (8-bits being compared simultaneously, with a single output bit

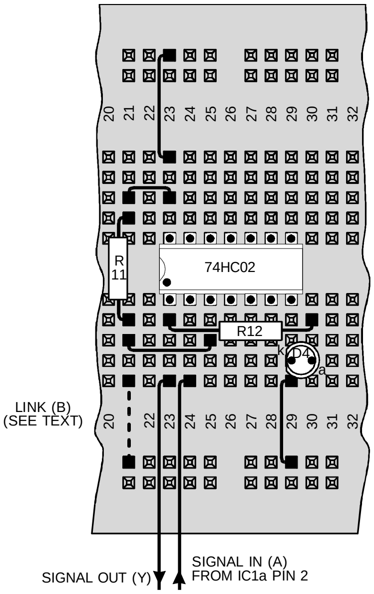


Fig.6.8. Breadboard layout for the NOR gate

being set to represent the answer).

XOR gates also allow, for instance, signal logic levels to be dealt with "as are" or inverted, just by changing the logic level on one input. One application for this is in the control of some simple types of liquid crystal display (LCD) – as we shall see later in the *Teach-In* series.

The quad 2-input XOR gate we want you to examine now is the 74HC86. Its pinouts are shown in Fig.6.9 – they are in the same order as the first three gates you examined. Use the breadboard layout shown in Fig.6.3, and run the usual tests.

XNOR GATE LOGIC

With an XNOR gate (Exclusive-NOT-OR), the output logic is the inversion of that which applies to an XOR gate. The logic symbol and truth table are shown in Fig.6.1f. Again the circle on the output indicates the inversion.

Whilst XNOR gates are manufactured, they are not readily available through hobbyist retailers and are not amongst the list of components we suggested that you bought for this *Teach-In* series.

However, we can actively demonstrate an XNOR gate via another of our interactive computer programs. The same pro-

PANEL 6.1 – HANDLING INTEGRATED CIRCUITS

Although modern integrated circuits (ICs) are very reliable, they have to be handled with respect. They must be inserted into circuit boards the correct way round, stated maximum voltages should not be exceeded, and current limits should be adhered to (although many devices have current limiting circuits built into them). One point which must always be observed, is that ICs should not be exposed to the dangers created by static electricity discharges, especially ICs which have the term CMOS (complementary metal oxide silicon) in their datasheet/catalog description.

Although we have not mentioned it before, all the ICs with the 74HC prefix that you have, and will be handling for this *Teach-In*, are CMOS devices. The 74HC type was chosen for its particularly hardy nature, including the ability to operate at up to 7V and to provide a reasonable amount of current to drive the LEDs. (Note that there are many other digital logic devices with a 74 prefix, but with a different set of letters following it, and with different characteristics.) Whilst CMOS devices have diodes protecting certain external connections, particularly the inputs, the diodes can only drain away excessive applied voltages up to finite limits. The discharges from static electricity can be many thousands of volts, levels that are way beyond what the protecting diodes can handle.

It is easy to avoid static electricity from discharging into an IC when handled by always touching a grounded item (one which is connected to electrical "earth") before touching it. This discharges static from your body or the tool you might be handling. The metal rear panel of a plugged-in mains-powered computer is a good place to touch; even its printer port cable has bare metal earthed connectors at each end.

In professional electronics, those handling ICs do so in conditions where sophisticated earthing techniques are used to prevent static electricity build-up. There is no need for the average constructor to go to such lengths and the "touching ground" method normally proves satisfactory. Also, any mains powered item of test or construction gear (e.g. soldering iron) should be firmly earthed.

Whenever possible, use sockets for ICs on any printed circuit board or stripboard (e.g. Veroboard) assembly where soldering is required. This enables the ICs to be easily replaced if necessary. It also prevents them from becoming overheated during soldering, even though they can be quite robust in this situation.

Do not feel unduly alarmed by the warnings about static electricity and its effect on ICs. Providing you observe the basic precautions, you can enjoy using ICs without endangering them, and most are actually far more resilient than many texts suggest.

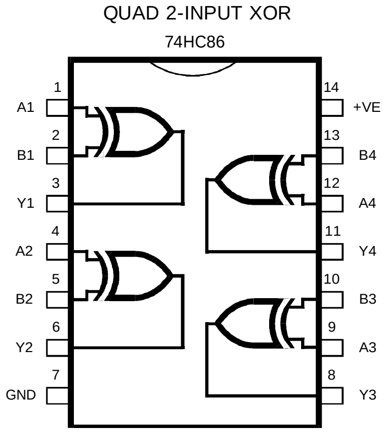


Fig. 6.9. Pinouts for the 74HC86.

gram allows you to examine on-screen the other logic gates we've been discussing. From the main menu, run the *2-Input Logic Gates* program.

LOGIC GATES PROGRAM

With the *2-Input Logic Gates* program running, the screen displays the logic symbols and truth tables for the six 2-input gates just discussed.

You can interact with any of the symbols, using the left and right keyboard arrows to select which one. The selected table is indicated by a light-blue background in the table heading.

Up and down keyboard arrows highlight different rows in the selected table. Notations on the logic symbol reflect the logic shown for the selected row. It is stated in binary (0 or 1) and red "flags'' also show whether the logic is high or low (just a bit of fun the author enjoyed putting in!).

We suggest you explore the symbols and try to memorize the logic tables (or at least the logic behind the creation of the tables, as discussed earlier).

PANEL 6.2 – SAMPLING RATIOS

You will recall that when discussing frequency counting in Part 4, we commented on the problems created by sampling at too slow a rate.

There is a simple ratio of minimum sampling rate to original frequency rate that allows the essence of the waveform (whether it's above or below a midway reference level) to still be discerned. The ratio is 2:1, i.e. sampling should be at a frequency no less than twice that of the waveform being sampled.

It was a certain Mr. Nyquist (dates and history unknown) who formally expressed this ratio, apparently defining the minimum sampling rate that allows accurate reconstruction of a signal in pulse-coded communications systems.

So far as audio signal sampling is concerned, where the shape of the waveform needs to be closely preserved, rather than its high or low status, a sampling frequency that is much higher than the frequency of the audio signal is required. This is very much apparent in the ADC Demo, which we discussed last month.

There does, though, seem to be a general consensus that for the upper audio frequencies (at the top end of human hearing) a minimum ratio of 3:1 is acceptable. It is worth noting that when reconstituting a digitally sampled audio signal back to analog, the harmonics created by the original sampling frequency need to be filtered out using additional electronic circuits.

SELF-TEST

When you are confident enough, have a go at another of our *Self-Test* options. Press <S> and correctly answer the questions asked! (We hope you will be mildly amused by the result of correctly answering each of them – and doubly so for getting all right!)

LOGIC WAVEFORMS DEMO

The next demonstration we've prepared illustrates two waveforms before and after they pass through three logic gates, AND, OR and XOR. Run program *Digital Sampling and Logic Demo*.

The cycle width for the input square waves displayed (Signals A and B) is changeable, and the waveforms traverse the screen to show how their relationships change with time.

All the control key options are stated on screen. When you press <P> the waveform for Signal B alternates between a narrow pulse and a square wave.

Whilst experimenting with different frequency rates, consider the implications of what the result would be if you were using one waveform to sample the other. In the screen demo, it's the AND result that is your best guide to sampling results.

You will see, for example, that when the edges of Signal A and Signal B cross, the ANDed result can be a pulse much shorter than Signal B's pulse. In any practical sampling circuit it is likely that some sort of additional circuit would be required to detect whether or not a sampled result occurs for less than a specified minimum duration.

If the result is too short, it

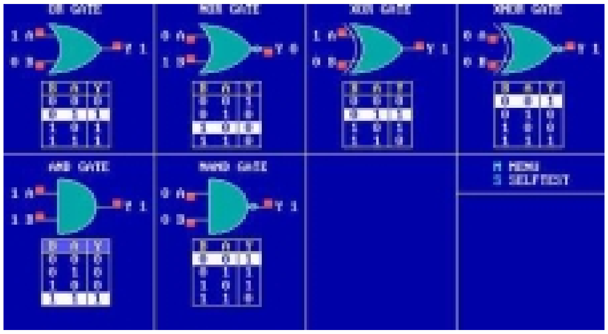


Photo 6.2. The interactive logic gates screen, in which all permutations of 2-input logic are demonstrated.

Photo 6.3. Interactive digital sampling demo screen, which highlights the relationship between two logic signals.

could be that it has been caused by “noise” in other parts of a complex circuit (think of how the electrical noise from some vehicles can interfere with your TV or radio reception).

There’s a snippet of further info on sampling in Panel 6.2. You will find Panel 6.3 interesting as well (relatively speaking!).

8-BIT LOGIC

Earlier in this Tutorial we discussed digital logic from the point of view of 2-input (2-bit) gates. It is now worth considering 8-bit logic, not in terms of actual electronic logic gate devices, but from the point of view of computers and computing programs. From the main menu select *8-Bit Binary Logic*.

The screen now displays six boxes comprising data for eight combined 2-bit versions (two bytes) of the logic functions previously discussed. The formula for each function is shown as (for example) Y = A OR B where the three letters are the same as those used in the 2-input gate logic demo.

Below the formulae are the eight 2-bit values for A and B, together with their Y answer. Eight steps are needed for you to produce the answer, taking each of the A/B bit pairs as separate items, combining them as required by the logic function stated. For information only, the decimal values for the full 8-bit binary values are given in green. (Binary/decimal conversion is examined a bit later in this Tutorial.)

We believe the rest of the screen’s functions are obvious, including the *Self-Test* option. Except – there’s a small clarification: when in the *Self-Test* mode and you want to use <M> or <S> to return to the menu or terminate *Self-Test*, you must press <ENTER> to activate the letter once keyed in. Otherwise, with the Control keys stated, just press and see what happens!

BINARY TABLE

Before we get into the business of illustrating binary conversion, have a look at the program *Binary, Hex, Decimal Table 0-255*. It’s what it says it is, decimal values from 0 to 255, with their 8-bit binary and hexadecimal equivalents.

There are three screen pages, rotating on a cycle at each press of the space bar (or any key except <M>, which brings back the menu display).

This table will prove invaluable on many a future occasion! Keep it on screen while you read this next section.

There is also a text file of the data that you can print out from your usual word processor

Photo 6.5. Interactive screen illustrating the principle of 8-bit logic functions.

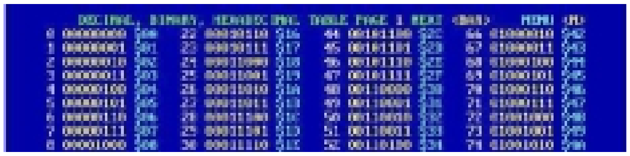


Photo 6.4. Part of the decimal-binary-hex conversion screen displays, covering decimal 0 to 255.

software. It's in directory C:\ TY2KPROG (where the rest of your *Teach-In* 2000 programs are held) and is named TY2KBDHX.TXT.

BINARY CONVERSION

So, you've had a glance at the binary conversion program pages, and you've been exposed to binary numbers in various ways since we discussed the installation and operation of your computer interface board in Part 4.

In case you've not yet figured-out the logic behind binary numbers, let's explain it here and now!

We've told you several times that digital logic can be in one of two states, variously expressed as high or low, logic 1 or logic 0, 1 or 0, on or off, H or L, set or cleared. Using 1 or 0 is the most convenient method of expressing binary numbers, in the same way that decimal values are expressed using the numeric symbols 0 to 9.

As you well know, in decimal we count from 0 to 9 and then cycle over to 0 again, but placing symbol 1 in front of 0 to produce 10 (ten), and so on.

In binary, we count from 0 to 1 and cycle back to 0, again placing a 1 in front of 0 to produce 10, but this time the symbol "10" represents decimal 2. Next we get "11" (decimal 3) followed by "100" (decimal 4), and so on. The sequence from 0 to 16 is as shown in Table 6.1.

In many instances it is conventional to place leading zeros before the binary value, so that its length is, for example, eight digits long (or 8 bits to use the commonplace term, where "bit" stands for binary digit).

Referring back to the conversion table still on your screen, you will see the 8-bit structure applied to the first 256 binary values. Yes, we deliberately said "256" rather than "255" – remember that 0 is a value as well!

So what about binary numbers beyond decimal 255? You just extend the principle: keep on increasing the length of the binary number, but, perhaps showing as two (or more) 8-bit lengths, separated by a space, e.g. 256 could be shown as:

00000001 00000000

or just 100000000

What you have probably spotted is that there are several situations in a binary number when just one bit is a 1, the others being 0. Run through the binary table on your screen – confirm that the single bit numbers and their decimal conversions are as shown in Table 6.2. Each of the decimal values is, of course, twice that of the previous one, and it is also a power of 2, as shown in the third column. From Table 2 we can get the values shown in Table 6.3.

You will recall that the bit numbers in binary are numbered from left to right as 7 to 0, which is the same order and number of the above power values.

What we can say, then, is that if a bit in a binary number is a 1, it represents the same decimal power of 2 as its bit number. If there is a 0 in a bit position, the value represented by that bit is also 0. For example, take the binary number 11010110, we can analyze it as illustrated in Table 6.4.

Try this with other binary numbers you think up, and cross-check your result with the conversion table.

HEXADECIMAL NUMBERS

We have commented that the symbols for decimal numbers run from 0 to 9 and that binary just uses 0 and 1. The hexadecimal (hex) system uses 16 symbols, 0 to 9 plus A to F. The

Table 6.1: Decimal and Binary Symbols

DECIMAL	BINARY
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111
16	10000
etc.	etc.

following thus applies:

Decimal 16 then becomes hex 10, decimal 17 = hex 11, decimal 31 = hex 1F, decimal 32 = hex 20, etc., always incrementing through groups of 16 before roll-over to the next prefix

Table 6.2

BINARY	DECIMAL	POWER
00000001	1	2^0
00000010	2	2^1
00000100	3	2^2
00001000	4	2^3
00010000	16	2^4
00100000	32	2^5
01000000	64	2^6
10000000	128	2^7

Table 6.3

POWER	7	6	5	4	3	2	1	0
DECIMAL	128	64	32	16	8	4	2	1

Table 6.4

BIT NO.	7	6	5	4	3	2	1	0	
DECIMAL	128	64	32	16	8	4	2	1	
BINARY	1	1	0	1	0	1	1	0	
VALUE	128	+64	+0	+16	+0	+4	+2	+0	= 214

symbol change, whereas in decimal you increment in groups of ten before roll-over.

This is illustrated in the conversion table on screen, where the blue values prefixed by "$" are the hexadecimal representations of the decimal and binary numbers to their left.

For incrementing from decimal 255 to 256, the roll-over becomes $FF to $100.

Hex values are indicated as such in a variety of ways. On screen now the symbol "$" indicates hex, the prefix "&H" is also used (as required by the QuickBASIC software in which the program you are now viewing was originally written). The letter "H" (or "h") is also often used as a prefix or suffix.

Value systems can also be stated by prefixes or suffixes of "b" or "B" (binary), and "d" or "D" (decimal). In some instances a numerical suffix is given to indicate the value system used, e.g. 100_{10} (decimal), 100_2 (binary), 100_{16} (hex).

Obviously, when there is any doubt about which system a value is expressed in, clarification should always be given, either in words, or as a prefix or suffix, unless the context in which it appears makes its value obvious. If, for example, you saw the value 100 written on its own, you might not be sure if it meant decimal 100, binary 100 (decimal 4), or hex 100 (decimal 256) – which gives obvious scope for confusion!

For the remainder of this text we shall use "$" to indicate a hex value.

DECIMAL															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HEXADECIMAL															
0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

BINARY TO DECIMAL

For converting binary or hex numbers to decimal you need a pen and paper, and/or a calculator (or the program we discuss in a moment!). Neither conversion is difficult.

Take a binary number of 00001101 00011001, for example (16 bits split into two groups of eight as discussed a moment ago). From right to left, write down in a column the bit numbers for each bit that has a 1 in it. Beside each bit number write down the value of 2 to the power of that bit number:

BIT	VALUE
0	1
3	8
4	16
8	256
10	1024
11	2048

Now add up the second column: 3353 in this example.

HEX TO DECIMAL

Converting a hex value to decimal is nearly as easy. Take $FD58 for example: from right to left, write down in a column the place number for individual hex numbers within the full number. In column 2 write down the value of 16 to the power of each position. In column 3 write the individual hex values themselves, and beside them the decimal equivalent for each of those values. Now multiply the values in column 2 and column 4, and write down the answer in column 5. Then add up column 5:

PLACE(x)	16^x	HEX	DEC	RESULT
0	1	8	8	8
1	16	5	5	80
2	256	D	13	3328
3	4096	F	15	61440

The total for this example is 64856.

DECIMAL TO HEX

It gets a bit more complicated for decimal to hex conversion. First, have the following table to hand:

Let's take decimal 39,923 as the example.

By inspection, establish which is the highest decimal value in the table that will divide into your starting value. In this case it is 4,096 and (noting that

POWER	VALUE
16^0	1
16^1	16
16^2	256
16^3	4,096
16^4	65,536
16^5	1,048,576
16^6	16,777,216
16^7	268,435,456

only integer values – whole numbers – are used in the division answers) the sequence becomes:

39923 / 4096	=	9 (= $9)
4096 x 9	=	36864
39923 - 36864	=	3059
3059 / 256	=	11 (= $B)
256 x 11	=	2816
3059 - 2816	=	243
243 / 16	=	15 (= $F)
16 x 15	=	240
243 - 240	=	3 (= $3)

Collecting the integer answers plus the final remainder gives us: 9, 11, 15, 3. Converting the decimal integer answers to hex gives: $9BF3.

HEX TO BINARY

We before go any further we must explain the term nibble that's about to be used. A nibble (or nybble) is a quaint computing term and refers to a group of four bits, whereas a group of eight bits is generally known as a byte.

Conventionally, a byte is split equally into two nibbles, left and right, comprising bits 7 to 4, and 3 to 0. You would not, for example, take the group comprising bit 5 to 2 as being a nibble.

Having clarified that, here's how to convert a hex value to binary:

Photo 6.6. Interactive decimal-binary-hex conversion screen, catering for up to 32-bit numbers.

First write down as a table the powers of 2 that make up a 4-bit binary value (nibble):

POWER	2^3	2^2	2^1	2^0
DECIMAL	8	4	2	1

Take as our example $A75D. The right-hand value is $D. Hopefully, you will recall, or can work it out, that D is decimal 13, which is made up from the following power-of-two values:

8 + 4 + 1 = 13

So your table now becomes:

POWER	2^3	2^2	2^1	2^0	
DECIMAL	8	4	2	1	
$D = 13 =	8	4	0	1	
BINARY	1	1	0	1	(nibble 0)

Therefore $D = 13 decimal = binary 1101.

In a similar fashion, work right to left taking each hex value in turn. In this instance to produce:

$5 = 5 =	0	4	0	1	
BINARY	0	1	0	1	(nibble 1)
$7 = 7 =	0	4	2	1	
BINARY	0	1	1	1	(nibble 2)
$A = 10 =	8	0	2	0	
BINARY	1	0	1	0	(nibble 3)

In reverse order, from 3 to 0, write down your nibbles:

1010 0111 0101 1101

which is the binary conversion for $A75D (or 10100111 01011101 as a 2-byte value rather than four nibbles).

VALUE CONVERSION PROGRAM

A program that allows conversion between decimal, binary and hex is available from the main menu: run *Binary, Hex, Decimal Converter*.

The program caters for binary numbers up to 32 bits long – decimal and hex maximums of 4,294,967,295 and $FFFFFFFF.

The central box is split into seven horizontal sections (see Photo 6.6). Sections 3 to 7 (Binary to Decimal) can be selected using the up/down arrow keys. In each section any individual character within the full value can be accessed using the left and right arrows.

The selected character can be changed and the result of that change is calculated in relation to the other four control-

PANEL 6.3 – RELATIVELY SPEAKING

An important concept to appreciate in electronics is that nothing happens instantaneously; everything takes a certain length of time to change from one state to another, whether it is a switch changing from on to off, or a voltage changing from one level to another, or just a fuse blowing.

It may seem that the switch is either open or closed, contacts either apart or touching, and at a molecular level this is true, but the physical nature of a switch means that because of the broad area of its conducting contacts, there is a period during switching off, for example, when the area of each contact which is actually touching the other is changing progressively from full-area contact to point contact, and only at the very final moment is the ultimate point contact broken.

During this period, the resistance between the contacts increases to the current flowing between them, and even at the moment when the physical point contact is broken, an electrical arc might be formed between the two open points, allowing current to still flow across them until they are even further apart. So much for the instantaneous nature of an on-off switch!

In digital electronic circuits, it is customary to think of the logic gates involved as responding to an instantaneous change from, say, logic 0 to logic 1 (from a low voltage to a high one). No such immediate change takes place, it takes time for the change to occur and there is a constant gradient through which the actual voltage level has to pass; it does not just suddenly jump from 0V to 5V, for example.

The time taken to make the transition may be short, possibly only fractions of a millionth of a second, but it still exists, and the concept of synchronicity – two things occurring at the same moment – is only a convenience when working out the logic of a digital circuit.

In reality, the synchronization of various actions taking place in order to create a further change is related to a "window" in time, during which all the required changes can occur at their own separate rates. The window could be a mere picosecond; it could be half of eternity; how it matters depends on what the circuit is required to do, and as long as all those changes happen while the window is "open", the circuit will behave as though they had all occurred at the same moment. But, if any of them occur outside the window, the result may be unpredictable and undesirable.

lable sections and the results displayed. Try it! The full range of control keys available is stated in the left-hand box.

We believe the display and its options are obvious, but we will just clarify one small matter: the "^" symbol will be seen in the *Bit Value* line, this indicates that the following number is a power (index), e.g. 2^4 means 2^4.

DIRECT ENTRY

The *Binary, Hex and Decimal Converter* program allows you to directly enter your own values for conversion. When the highlight is active on one of the five Binary to Decimal options, press <ENTER>. At the bottom of the screen, value entry then becomes available. Enter the value, press <ENTER> again and the value is converted to the other modes.

There are a few intercepts to prevent you "crashing" the program with most practical joke entries! (But nothing to stop malicious intent if you are really set on it! If you do get the screen messed up, return to the menu and re-select the program.)

SELF-TEST

Press <S> to test your understanding of bin-hex-dec conversion! With a bit of practice, and reference to our earlier discussions, you should find that it's actually easier than you might think.

Note that when asked to convert a value to binary, you enter the answer in groups of nibbles separated by a space. This makes it easier to examine your answer if it's wrong.

If you really cannot work out an answer, press <A> plus <ENTER> for it to be revealed. But it's worth trying to get answers for yourself, the ability to do such conversions is invaluable.

MORE EXPERIMENTS

You've learned that you can count on us to offer you some interesting hands-on ideas each month – you can count on us again in this month's Experimental section, so clock onto it!

NEXT MONTH

In part 7 we examine opamps, which are integrated circuits for use with analog signals and voltages. Amongst other things, opamps allow waveforms to be amplified, mixed, and generally processed in a variety of ways. We shall illustrate their principles and some of the ways in which they can be used, to allow you, for example, to listen to the waveforms we discussed in Part 5.

TEACH-IN 2000 – EXPERIMENTAL 6

BINARY AND DECIMAL COUNTERS

In the latter part of this month's Tutorial, we discussed binary numbers and the way in which they relate to decimal and hexadecimal values. We are now in a position to introduce an integrated circuit that allows you to physically see the binary counting process in action. We refer, of course, to a binary counter plus some LEDs!

There are numerous types of counter manufactured, with such descriptive names as binary ripple counter, synchronous binary counter, asynchronous binary counter, binary-coded-decimal counter, Gray counter, decade counter, Johnson counter, up/down counter, and so on. Far too many to discuss in detail – and there are even variants on these!

We shall just concentrate on two types, a 7-bit binary ripple counter, and an 11-output decade counter.

BINARY COUNTER

The 7-bit binary ripple counter we shall use is the 74HC4024. Find one from your components bag and connect it into your breadboard, together with the required LEDs and resistors, as shown in Fig.6.10. As usual, touch a grounded (earthed) item to discharge static electricity from your body before handling the device (and ensure that it's the right way round!).

If you only have five 470Ω resistors available, you could use any value between 100Ω and 1kΩ for the other two.

Connect up power and watch the LEDs while adjusting the oscillator for different frequencies.

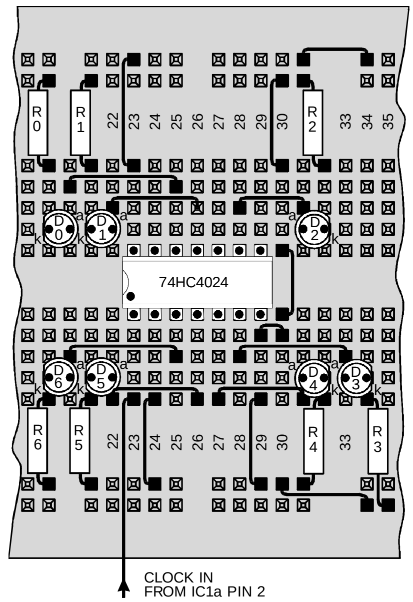


Fig.6.10. Breadboard layout for the binary ripple counter experiment.

SYMBOLICS

The circuit diagram for this setup is shown in Fig.6.11, and the pinouts for the 74HC4024 are in Fig.6.12. Unlike with logic gates, there is no "official" symbol to illustrate the nature of this device (which is increasingly the case with integrated circuits that become more and more complex).

What we have to content ourselves with is a boxed outline with some pin numbers and their descriptions. In the circuit diagram, note first the pins to which the power lines are connected. As with the logic gates discussed in the Tutorial these are pin 7 for 0V (GND) and pin 14 for +VE (this is not always true for other digital devices). The recommended operating voltages are between 2V and 6V, although this device will withstand up to 7V for short periods (but never above 7V).

The Clock input is the next important pin. This is the pin into which the data pulses that the counter has to count are input. The ">" symbol in the pinout diagram also indicates that this is the Clock input pin. It is frequently omitted in many circuit diagrams.

Note also the small circle at this input pin. It indicates that inside the device the pulse logic level to which the device responds is "inverted". You met a

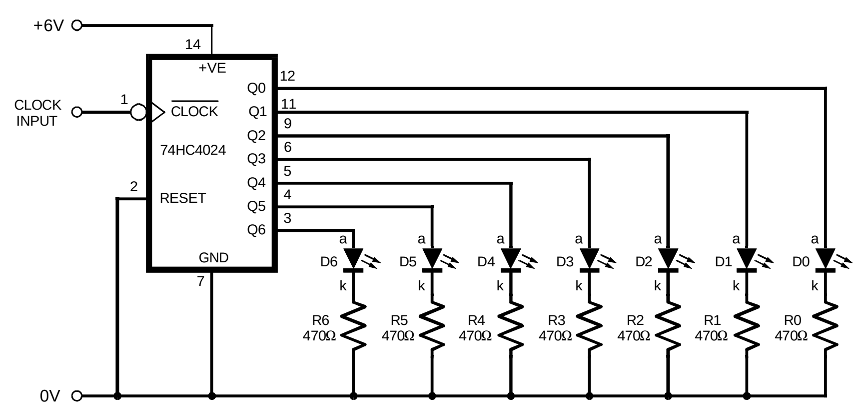


Fig.6.11. Circuit diagram for the binary ripple counter experiment.

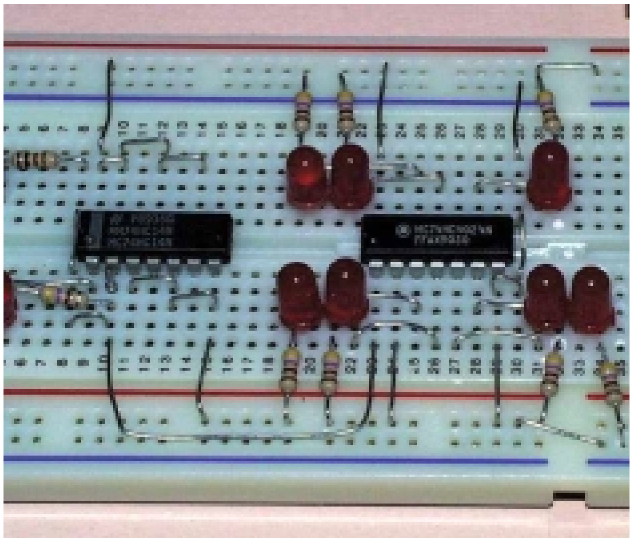
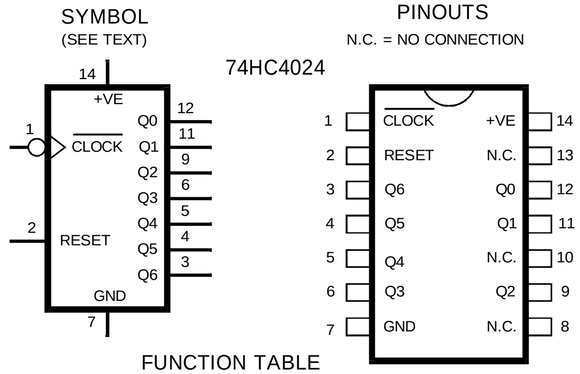


Photo 6.7. *Breadboard showing the binary counter and LEDs. Part of the oscillator is shown at the left.*



FUNCTION TABLE

CLOCK	RESET	OUTPUT STATE
↑	L	NO CHANGE
↓	L	ADVANCE TO NEXT STATE
X	H	ALL OUTPUTS ARE LOW

X = DON'T CARE

Fig.6.12. Symbol, pinouts and function table for a 74HC4024 binary ripple counter.

similar situation with the NAND, NOR and XNOR gates, although in their case the inversion took place on the output data.

The significance about the logic level to which a device such as a counter responds is important to note. Many devices do not respond to the actual voltage level at an input (as did the logic gates in the Tutorial) but to the change in logic level.

In the case of the 74HC4024, the change responded to is that from high to low, and the counter adds 1 to its internal count value. The device is said to respond to the trailing edge of a pulse (a term we used when looking at pulses in the Tutorial).

When the pulse changes from low to high, the device does not respond in any way and the count remains as it was. (The 74HC4017 we shall use later responds to the change from low to high – i.e. to the leading edge).

Be aware that not all circuit diagrams show the inversion circle even though inversion occurs. Some circuits show a bar line above the description for such a pin (as we have done in Fig.6.11). Indeed, the use of a bar to signify inversion is arguably more commonplace than the circle.

RESET LOGIC

Pin 2 of the 74HC4024 is the Reset pin. When Reset is at logic 0 (low), the counter is permitted to count any pulses that enter the Clock pin. Two things happen when the Reset pin is taken high (logic 1). First, the entire count within the device is reset to zero. Second, the counter is prevented from counting any further pulses until Reset has been returned low.

Note that in some types of counter, Reset may be active-low, in other words, Reset occurs when the pin is set low (logic 0), but counting is permitted when the pin is high.

The terms active-low and active-high are frequently encountered in electronics. The latter means that the stated function (Reset, Clock, Enable, etc.) is permitted or occurs when that pin is taken (or is already at) high.

"Q" OUTPUTS

The remaining useful pins are labeled Q0 to Q6 (in some circuits or pinout diagrams, they may be labeled as Q1 to Q7). Note that three pins have no function (8, 10 and 13). Note also the use of "Q" to signify an output; conventionally, this is the letter normally used with digital devices such as counters (whereas "Y" was used with the gates, earlier).

We have said that the 74H4024 is a 7-bit counter. Pins Q0 to Q6 are the outputs at which the seven bits of the internal binary count value are accessed. Referring you back to what you have learned about binary numbers, output Q0 corresponds to bit 0, Q1 to bit 1, etc. It is to tie in with this numbering that the resistors and LEDs are numbered from 0 to 6 in Fig.6.11.

BINARY COUNT-UP

If you run the 8-Bit Binary Logic program and set the 8-Bit OR line A to zero, and then keep pressing the <+> key the binary sequence will count up in ones (increment) at each press, from 0 to 255 and then back to zero to start counting again.

This is what's happening inside the 74HC4024 (except that it only has seven bits). From a reset value of 0000000, it will increment each time the clock pulse goes from high to low. When it reaches a count of decimal 127 (binary 1111111), at the next negative-going clock pulse it rolls-over to 0000000 again.

That, then, is the sequence you should be seeing on the LEDs connected to your 74HC4024 (although the breadboard space available prevents them from being inserted in the ideal visual sequence).

As with the logic gates, there is a truth table for the 74HC4024, except that it is actually referred to as a Function Table and takes a somewhat different format. It is shown as part of Fig.6.12.

The table shows the output state in relation to the conditions on the counter's Clock and Reset pins. Note the upwards and downwards waveforms in the clock column. The first signifies the rising (leading) edge of an input clock pulse, the second shows the falling (trailing) edge. These are commonly encountered symbols in digital electronics.

If the counter's Q0 to Q4 pins are linked to the computer interface input pins IN0 to IN4, you can observe the count sequence for the first five bits via the *Parallel Port Data Display/Set* program. With the oscillator rate set slow enough, the bits will be seen to change state in the two upper boxes, with the actual decimal value that the bits represent shown in the *Corrected Input Byte* box.

FREQUENCY DIVISION

A further experiment you can try is to select any of the counter outputs as the source of the data signal when running the *Computer As Frequency Counter* program.

This will enable you to really wind up the oscillator rate, yet still be able to see a meaningful frequency value displayed on screen (which you should mentally multiply by the division rate provided by the counter pin selected – each output is at half the rate of the previous one, remember!).

What we also suggest you do is to put the 74HC4024's Reset under computer control. Disconnect the link between the counter's pin 2 and 0V. Now link pin 2 to OUT2 of the interface. Repeatedly pressing key <2> will then cause the counter to run or be reset. You should be able to see the result on the LEDs and on the screen.

If you are feeling further adventurous (and why not?!), also

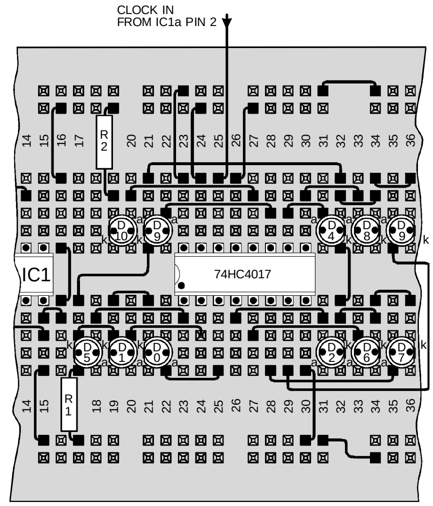


Fig.6.13. Breadboard layout for the 74HC4017 decade counter.

disconnect the counter's Clock input pin 1 from the oscillator, and couple it to interface OUT3 (controlled by key <3>). This puts the counter's Clock and Reset total under finger-tip control. The Mutual Melding of Man, Mind and Machine, no less!

RIPPLE

Ripple, incidentally (but significantly), in this context refers to the way that the counter's internal sections respond. (Note that ripple has a different mean-

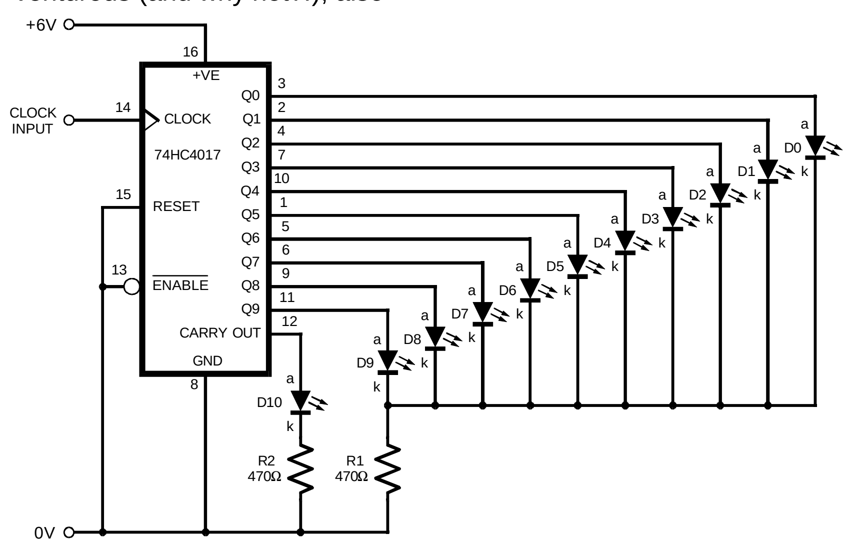


Fig.6.14. Circuit diagram for the 74HC4017 decade counter.

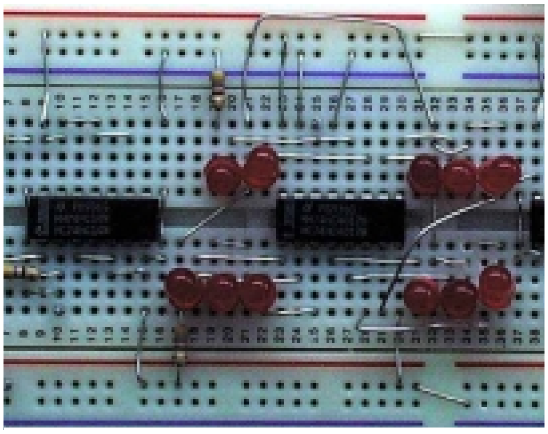
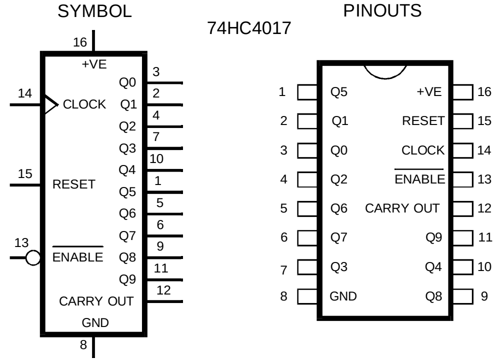


Photo 6.8. *Breadboard showing the decade counter experimental circuit, with part of the oscillator seen to the left, and part of the ADC chip to the right. Take care that crossing link wires do not touch.*



FUNCTION TABLE

CLOCK	CLOCK ENABLE	RESET	*OUTPUT STATE
L	X	L	NO CHANGE
X	H	L	NO CHANGE
X	X	H	RESET COUNTER Q0=H, Q1 TO Q9=L C.O.=H
↑	L	L	ADVANCE TO NEXT STATE
↓	X	L	NO CHANGE
X	↑	L	NO CHANGE
H	↓	L	ADVANCE TO NEXT STATE

X = DON'T CARE
*CARRY OUT = H FOR Q0, Q1, Q2, Q3 OR Q4 = H
CARRY OUT = L OTHERWISE

Fig.6.15. Symbol, pinouts and function table for the 74HC4017 decade counter.

ing in the context of power supplies – which we will discuss later in this *Teach-In* series.) In simple terms, the counter contains several divide-by-two circuits in a chain. It takes time for each counter to react to a trigger pulse from the preceding counter.

The delay is only short (nanoseconds for the 74HC4024), but the total delay as the pulses ripple through stages to the final output can be critical to other circuits, which may rely on the synchronization between a multi-stage counter's clock pulse and the setting of an output pin.

There are counters in which the internal circuitry is designed so that each section is triggered at the same time. These counters are referred to as synchronous.

DECIMAL COUNTER

When you can tear yourself away from the fascination of binary counting, have a look at the attributes of a decade counter, the 74HC4017. Remove the 74HC4024 and insert the 74HC4017. Connect its pins as shown in Fig.6.13, complete with LEDs D0 to D9 and resistors R1 and R2. You will need to "steal" the tenth LED from the oscillator, unless you bought more than the suggested quantity of 10. Ignore D10 for the moment.

Power up your breadboard and watch the sequence of the LEDs. Adjust the oscillator rate so that you clearly see the steps of the count.

Whereas the 74HC4024 counted in binary, from 0 to 127, the 74HC4017 decade counter counts in steps from 0 to 9, rolling over to begin the count from 0 again following 9. During the count only one output is ever high at any time.

The pinouts for the 74HC4017 are shown in Fig.6.15, the circuit diagram for the connections on your breadboard is illustrated in Fig.6.14. Again the LEDs are numbered from zero to correspond with the output numbers. Note that only one ballast resistor (R1) is needed for the 10 LEDs D0 to D9, since only one can ever be on at once.

You will see from the circuit diagram that, in common with the binary counter, this decade counter has a Clock input (pin 14) and a Reset pin (pin 15). As we said earlier, the 74HC4017 increments the count on each rising edge of the clock pulse.

The count is reset to 0 when the Reset pin is high. However, when the Reset pin is low, the continuation of the count depends on the status of a third pin, Enable, pin 13. Not surprisingly, this pin enables or inhibits the clock count. Because there is a bar-line above the word Enable (or a circle on its input), we know that the counter is enabled when the pin is low.

The ten outputs are labeled Q0 to Q9, which ties in with the count value that a logic 1 on the respective pin represents.

The function table for the

74HC4017 is shown as part of Fig.6.14. An interesting point to note is that the Enable pin can also act as a clock signal to the counter. When Clock is held high and Enable is taken from high to low, the count advances to the next state.

In most circuits it is more usual to use Clock rather than Enable as the clocking signal. However, what this option highlights is that Enable should never be taken low when the clock is high if you wish to preserve the count value existing at the last clock pulse.

It is subtleties like this that abound in digital electronic circuits, especially when the overall circuit complexity is great. You always need to consider the implications of how the timing of different signals can affect the response. In reality, at this stage of your learning, you need not concern yourself about them. When you are ready to consider them, you'll find that data sheets give typical timing values for practically everything!

There is an eleventh output pin, the Carry Out pin. This pin goes high when the counter is reset or rolls over to zero. It remains high until a count of five is reached.

The Carry Out signal is of benefit in a variety of situations; such as where you might wish to couple (cascade) two or more decade counters in series, for example. In this case the rising edge of the Carry Out signal would be used as the clock pulse for the next stage. Thus the first counter would count units from 0 to 9 and the second stage count the decades from 10 to 90. A third stage could count the hundreds, 100 to 900, and so on.

Observe the Carry Out pin in action by removing, say, the LED from one of the outputs (but not from outputs 0 or 5). Add the LED to the Carry Out pin as D10, via the already inserted resistor R2). Power back up again and observe the sequence.

As with the 74HC4024, you can connect up to five outputs to the computer interface at IN0 to IN4. You can also connect the Clock, Reset and Enable pins to the interface outputs OUT2 to OUT4, controlling them from your keyboard when running program *Parallel Port Data Display/Set*.

So there's a whole raft of ideas to play around with until next month. You could also include some experiments with the logic gates, interfacing them to the computer and counters as well. Till then this author's out for the count!

CORRECTION

In Part 5, Fig.5.6. Add link wire to join rows E and F of column 42.

Go to next section

Circuit Surgery

by ALAN WINSTANLEY & IAN BELL

Onwards with our opamps extravaganza we go, unearthing more of the inner workings of these essential electronic workhourses. Plus more questions and answers from our postbag as well.

Following several readers' enquiries we received concerning opamps (operational amplifiers), last month we provided a summary opamp selector chart, which illustrated the often-gargantuan differences between individual types. There are thousands of opamps available, often optimized for a particular use and in demanding applications (e.g. instrumentation or low-power circuits) the choice of device type can be very critical.

It's a good idea to decide on the factors which are most important in your application (input impedance/slew-rate/ power consumption?) and then choose a likely-looking device using our selector as a guide, or check the major catalogs for guidance. Also, many manufacturers now have web sites from which data sheets can be downloaded, and using the data in our previous articles you will be able to navigate through the minefield of opamp parameters and specifications more easily.

OPAMPS – GETTING LOADED

We now continue to investigate opamp characteristics and techniques. We described the basic *differential amplifier* last month, which we have drawn again in Fig.1. Opamps should have a very high voltage gain, so the voltage gain of our differential amplifier should be as high as possible.

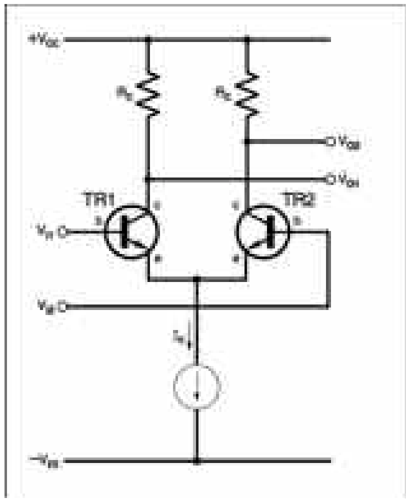


Fig.1. Differential amplifier formed from a matched pair of npn transistors

Any transistor used in the amplifier will have a (more or less) fixed gain, but this is in terms of its *current* output, i.e. its *collector current.* Variations in the transistor's base-emitter voltage and base current will cause large variations in its collector current. The collector current flows through the collector resistor, *R*c, giving rise to the output voltage, *V*o.

By Ohm's Law, ***V=IR***, so for a given current variation, then the larger we make *R* the larger the *voltage variation* will be. This means that the larger we make *R*c, the larger the voltage gain of the differential amplifier. This seems straightforward enough – just use large values of *R*c and we get a nice high gain: after all resistors are cheap and large values don't cost any more than smaller ones!

Unfortunately it's not that simple. First of all opamps are usually integrated circuits (ICs) where large resistors *do* cost more – they take up more space (silicon real estate!).

Furthermore, it is difficult for IC makers to fabricate precise resistance values, so there can be comparatively few resistors on a typical chip. Secondly, the transistors have to operate within a certain range of bias currents, below which they may give poor performance in terms of gain etc.

If we use large resistors and keep the supply voltage the same, we have to reduce the bias current, possibly to an unacceptable level. Alternatively, we can always increase the supply voltage, but do you really want an opamp that requires a 100V supply?

This seems like a no-win situation, but happily the **current mirror** circuit comes to our rescue. Although a current

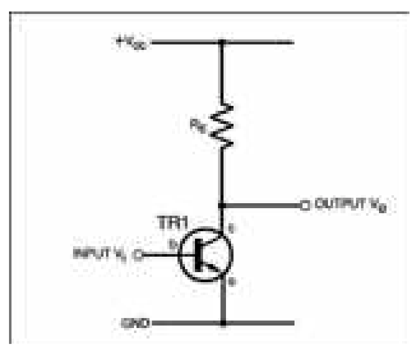


Fig.2. simple single-transistor amplifier.

source has a very high resistance (ideally infinite, in fact), any current we choose can flow from it.

Thus, in our opamp circuit we can set up a current source outputting the appropriate bias current, and use it in place of the collector resistor; the transistor gets the correct operating current it needs, and we get a high voltage gain due to the very large effective resistance of the current source. See May and June '99 *Circuit Surgery* for a detailed explanation of transistor current sources.

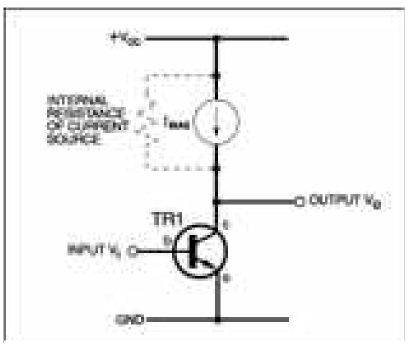


Fig.3. Simple transistor amplifier with current source load (active load).

BIASED APPROACH

Before seeing how we apply this to our differential amplifier, it is easier to have a look at a simple one-transistor amplifier, and at this point it is useful to recall the idea of biasing in more detail. Consider Fig.2, a very basic transistor amplifier. It is biased by applying a DC voltage to the base (not shown), and often a potential divider is used for this purpose.

The input signal varies around the bias voltage, so for example if the bias voltage was 0·65V and the signal was 0·02V peak-to-peak, then the bias voltage would vary from 0·64V to 0·66V. The bias current causes a certain collector current to flow (call this I_{BIAS}) which results in a certain voltage drop across the collector resistor.

As the signal varies, the collector current varies around I_{BIAS} causing the voltage drop across the collector resistor to vary as well. This action produces the (amplified) output voltage signal. We can think of the bias and the signal as two separate components of the collector signal, which when added together give the overall action of the circuit.

It does not matter where the bias "comes from", so we could apply the bias current directly to the collector circuit by using a current source as shown in Fig.3. With no signal applied the base voltage would adopt the appropriate voltage (0·65V in our example), always assuming than the required base current could be supplied to the base (the means for this is not shown, but in a real circuit the base would obviously be connected somewhere to achieve this).

ACTIVE LOAD

When we applied the signal to the amplifier, we would force the collector current to something other than I_{BIAS}, and in order for the current to be maintained through the constant current source the difference, i.e. the signal current, would flow in the internal resistance of the current source. Now this resistor is large and therefore results in a very large voltage gain (a small current change results in a large voltage change).

A current source used to get high gain from an amplifier in this manner is known as an *active load*. The schematic for a basic implementation of Fig.2 is shown in Fig.4.

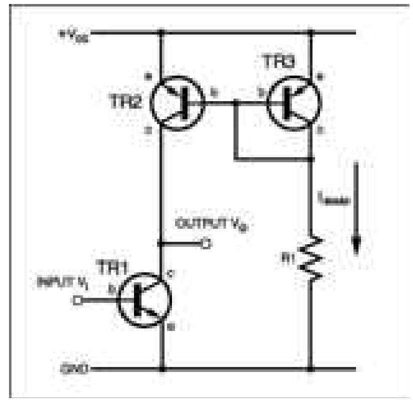


Fig.4. Schematic of transistor amplifier with active load.

We can use an active load with the differential amplifier, but the situation is a little more complex because we have to be careful not to upset the symmetry of the circuit. If we used two separate current sources for the two transistors, we may not be able to match the currents accurately enough to the emitter bias current.

The reason this matching is difficult (unlike the two transistors in the differential amplifier itself which are well matched) is that if the emitter current source and differential amplifier transistors are *npn* then the active load will be *pnp*, and it is difficult to match *npn* with *pnp* transistors. The solution is use a current mirror with its reference connected to one differential transistor and its output to other. This is shown in Fig.5.

It looks like even this approach breaks the symmetry of the circuit (TR3's base connection is not the same as TR4's), but as far as *current flow* is concerned the circuit is still symmetrical. When a differential input voltage is applied, the amplified output difference current on TR2's side is dropped across the current mirror's very

large internal (output) resistance. So we get a highly amplified voltage signal at TR2's collector.

However, TR4 is wired like a forward biased diode (the transistor's base-emitter junction) and therefore has a low resistance. The *voltage gain* at TR1's collector is therefore low and this output cannot be used. With an active load the differential amplifier has to be used with a single ended output.

We'll be rounding off our opamp mini-tutorial next month, by looking at the output side of things, including ways of implementing short-circuit protection. *IMB*.

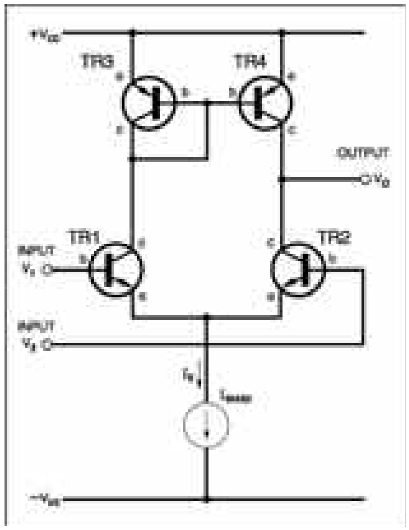


Fig.5. Differential amplifier with higher gain due to active load. Transistors TR3 and TR4 form a current mirror

SOCKET TO ME

David Preston asks: *"I have a question on the use of dual in-line (DIL) sockets. I have several designs that use an opto-triac operating at mains voltages. Could you tell me the maximum ratings of a DIL socket? Would they be suitable for a DIL opto-triac or should I solder the device straight to the board?"*

The typical contact rating of a DIL socket is at least 1A or more. Harwin is a well-known maker and their catalog of turned-pin sockets quotes a rating of 2A per pin, with an insulation resistance of 500V (which I would interpret as the maximum voltage allowed between two adjacent pins).

Another maker (Augat) is quoted at up to 3A with a dielectric strength of 1kV RMS (1·4kV peak). However, I would hate to hang a 750W mains load on such a socket! I would prefer say 50W to 100W or so maximum as a safe rule of thumb.

There are two types of DIL socket – the "leaf" type uses a pair of wiping spring contacts on every pin. The entrance to each contact is large, and the IC pins are gradually guided into alignment using automatic or manual insertion equipment.

More expensive precision "turned-pin" sockets make a good contact with the four corners of each IC pin and require that the chip must be pre-aligned, but they tend to be easier and smoother to work with. The idea is to produce a gas-tight seal around the four points of contact, to ensure a noise-free and reliable joint. The current ratings of both types is about the same, but I would say that the "leaf" type will have a stronger joint.

Personally speaking, with any opto-isolator or triac device controlling mains loads, I would want to solder it directly to the board, so that there are nice "meaty" solder joints that will help with the current-carrying capacity of the joint. The PCB's copper tracks will also help to heatsink the device as well, and for this reason audio amplifier ICs are always best soldered direct to the board rather than using a DIL socket. *ARW*.

SURFACE-MOUNT SELECTION

"I would like to ask what the term "MSOP" stands for: I have a school project in mind using a TC07 to detect temperature and wondered if the MSOP version would be suitable? Thank you!"

This question was posed in the *EPE Chat Zone* message board of our web site. MSOP simply means *Moulded Small Outline Package.* Anything with "SO" in its description means "Small Outline" and should immediately set alarm bells ringing!

It means you're looking at the tiny surface-mount version, which will be unsuitable for most school or hobbyist projects because of the steady hand needed to position and solder them reliably by hand, although you could try if you fancy a challenge. Otherwise be sure to buy the ordinary discrete version instead.

Here is a mini-glossary of some abbreviations used in this area:

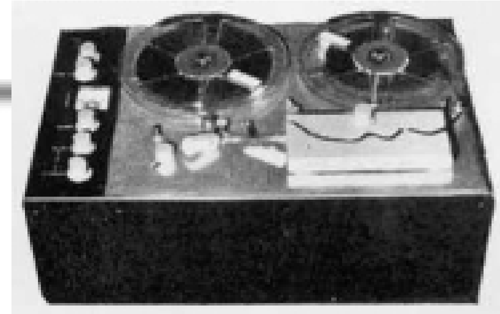
CERDIP: Ceramic dual-in-line package
DIP: Dual-in line package
LCCC: Leadless ceramic chip carrier (20 to 84 pin, square body, no leads).
LDCC: Leaded ceramic chip carrier
PLCC: Plastic leaded chip carrier (square-style SM chip)
PQFP: Plastic quad flat-pack

QFP: Quad flat-pack
SMC: Surface mount component
SMD: Surface mount device
SMT: Surface mount technology
SOIC: Small-outline integrated circuit (generic surface-mount IC)
SOJ: Small-outline with “J”-shaped leads
SOMP/MSOP: Molded small-outline package
SOP: Small-outline package (for surface mounting)
SOT: Small-outline transistor

Take it from someone who knows, it’s dead easy to order a surface-mount device by accident so you need to pay close attention to the catalogs (and data sheets) when ordering. *ARW.*

Go to next section

Special Feature



TELCAN HOME VIDEO

by Barrie Blake-Coleman

The true story of a British "first" in home video recording.

Britain stands pre-eminent in creative science and engineering, but the depressingly long list of "lost" British firsts in invention shows how often thwarted or disillusioned British inventors and innovators have either abandoned their ideas or gone abroad, thereby reducing British competitiveness. Decades of British under-investment in British ideas and British technologies has meant that other nations either independently develop the same ideas, or directly capitalize on British technical creativity – and soon overtake Britain in their own markets.

Just such a story is that of Norman Rutherford and his partner Michael Turner, who have learnt this lesson and are quick to remind us. They should know, back in the early 1960's they not only developed the first domestic video record and replay system, but also the first combined TV and VTR and the first Camcorder; but, it is claimed, poor foresight by their backers and investors lost them the edge.

MAKING A PICTURE

The announcement of the *Cathodian* Vidicon 3-inch TV camera tube early in 1960 took the attention of both Norman Turner and Michael Rutherford. The possibility of a new product for their Nottingham Electronic Valve Company (N.E.V.Co) was compelling. They wanted to develop a small CCTV system but the broadcast standard camera tubes were far too bulky and expensive.

The Cathodian device now made matters simpler. Cost was still a problem so, not requiring the full TV standard quality, they negotiated with Cathodian to buy all the slightly imperfect tubes (one or two drop-outs on the video array).

Oftimes a genius in circuit design, Michael developed the camera electronics using just four stages from two thermionic valves. This miracle of economy was based on an ECC82 double triode and an ECL82 triode pentode valve. The first provided a video amplifier and diode mixer, the second a triode RF oscillator and power output stage for the horizontal scan coils.

The vertical signal was obtained from a mains-ripple supply, giving a usable mains locked sawtooth. *"It was a unique – if not eccentric, piece of design typical of Michael and myself, but it worked like an absolute dream,"* so commented Norman Rutherford recently.

The whole camera assembly, designated *NEV1 Mini-Eye* in its initial design, sold for 150 UK pounds and outpriced and outperformed anything around. It was 250 UK pounds less than its nearest competitor, but the "transistorized" version soon appeared from their development bench and at 72 UK pounds was even more astonishing.

Advertisements elicited an inspiring response. Domestic and international sales rocketed – an order for 4000 cameras came in from Germany. An absolute triumph given that the Germans held the British electronics industry in low regard.

TAKE OVER

The then senior engineer at Granada TV, Reg Hammons, saw a trade advert for the *NEV2* and thought the camera would be good for mobile outside broadcasts and rehearsals. He mentioned his viewing of the camera to Sidney (later Lord) Bernstein then head of Granada.

Bernstein flew to Nottingham and at a meeting with both Norman and Michael learnt that not only was manufacturing capacity very limited, but the development of the camera had so depleted the company's reserves that they were unable to meet anything approaching a substantial order. He then asked how much they would need to continue R&D and production. *"Too much."* said Norman *"About half the value of the Company".*

"What is that amount" asked Bernstein. *"About £20,000,"* said

Norman.

"That's petty cash." Bernstein said and instructed his accountant to write a check there and then.

The company now had a new owner, but though Bernstein had a 75 per cent stake, both the original partners were appointed directors with full management of the company's operations. All debts were paid off. More to the point they now had no limits to what they could spend on R&D.

IN A SPIN

Reg Hammons made frequent trips from Granada to liaise with the company on behalf of Bernstein. On one occasion he mentioned that he was aware of a large effort taking place in the US and Japan to develop a video system for recording broadcast TV at home. Ampex had developed the helical scan system for professional users in the US in the middle fifties and the same approach was being tried for domestic recorders.

At first they tried a narrow bandwidth design based on a domestic audio recorder to emulate the high-speed wire and metal tape recorders already used by the big broadcasting operations.

It was the path of least resistance – no one actually knew what the maximum frequency limit was on very high speed recording and so they converted two 0·25-inch reel-to-reel Grundig and Ferrograph AF recorders to run at 60 and 120 inches per second (IPS). Surprisingly, enough video information could be recorded at 60 IPS to create a shadow of a picture; at 120 IPS it was *"just recognizable"* but a lot more work needed to be done.

But months of work gave little in the way of encouragement. Then, in January of 1962, Michael Turner discovered in the course of examining head driver methods that a considerable improvement in signal-to-noise could be achieved by introducing significant pre-emphasis on the driver signal.

"There is a popular point of view, originated by Emerson, which assumes that building the first, or a better mousetrap, results in people beating a path to your door – this must be the most pernicious fallacy ever to misrepresent invention."

Hammons thought there could be a large market for home video recorders and urged the two to have a go at developing a system for the British market. The idea found a receptive audience, the mini-eye camera had sold well but now orders were tailing off.

It was known that Ampex had solved the video tape problem using four rotating heads producing a helical scan – but this was an expensive option for a home video system.

The improvement was so profound that it implied that a broadcast quality picture could be achieved quite soon. Unfortunately it was also a damaging revelation – the improvement was genuine but simply took the existing operational limits in a different direction.

HEAD TO HEAD

The main problem was identified as the record and replay heads. The head gap was too wide to give the high frequency response necessary to approach the ideal 3MHz needed to reproduce the full video bandwidth of the 405-line system. It was also determined that the lowest response able to give a wide enough gray scale to enable the picture to have clarity was 2·5MHz.

Something needed to be done to eliminate the head problem and give the designers a chance to grapple with the other aspects of the video processing. A narrow gap head was produced from an existing Ferrograph unit, but even without AC bias on the tape (rather, a heavy DC bias directly applied to the tape by means of a permanent magnet) and heavy pre-emphasis on the video signal, the best that could be achieved was 2MHz. *"It just got by"* Norman Rutherford recounted, but it had to be better.

Unfortunately they had a seemingly intractable problem. The narrower the head gap, the lower the magnetic path reluctance around the gap became. Thus, the greater the flux shunt around the gap, the more the signal field was shared between the gap and the leakage path.

The result was that as the response was increased with a narrowing gap, so the signal-to-noise ratio worsened. A mu-metal Ampex head (intended for HF telemetry and imported from the States) was one possible solution, but it was prohibitively expensive. The only recourse was to design one themselves!

Many months of work led inevitably to a design which avoided the conventional problems associated with ordinary heads – they plumped for a cross-field head where the passive section was made of two screw adjustable copper arms nominally

separated at the rear by a 200 micron gap with a tape face gap of just under 50 micron. The active section carrying the coil laterally straddled the two copper arms and this design gave the necessary bandwidth.

Nevertheless, DC bias was still employed as too a considerable amount of pre-emphasis. But by contriving an overwind on the final video driver stage's inductive load, the effective bandwidth shot up to well in excess of 2·6MHz. The replay signal was, of course, still highly differentiated and this was equalized by employing a series of 3db/Octave integrators and phase correction circuits to recover the original signal.

Tape speed still needed to be high (120 IPS for broadcast standard recording) but by using 12,000 feet of 0·25-inch triple play tape on 10·5-inch spools (for increased play time and better head wrap) the record time was extended to over 20 minutes. An added advantage was the narrow video and audio track widths (the latter FM modulated on a second head), this narrow track enabled the tape to be turned over and recorded on the other side.

More to the point, the replay produced a very good video

Telcan unit playback demonstration at its launch in 1963. The early prototype (1962) model is shown in the heading.

FIRST MEETING

Norman Rutherford and Michael Turner were school friends in the war years, having met one Wednesday afternoon on the school football field during a sports period. They found themselves in trouble when the sports master espied them rooted to the spot in mid-field, deeply engrossed in discussing a design for a radio control circuit – a small error for both, since Michael was on one side and Norman was the opposing goalie!

Norman's father owned a radio retailers and then, later in the fifties, a television retail and repairs shop in Nottingham. Michael's father was the proprietor of a garage, and thus both boys developed against a background of technology and engineering.

Later, in 1952, the two boys met again as college chums at the *Peoples College* in Nottingham, where both developed an abiding interest in electronic design, becoming immersed in the white heat of the post war broadcasting and electronics age. They bought government

TV RECORDING AT HOME ON £62 UNIT

BRITISH EQUIPMENT DEMONSTRATED

U.S. contract for Telcan units

Now it's taped TV for the home

By Our London Correspondent

Norman Rutherford (right) and Michael Turner (left) with their wives and a Telcan "Combi" set at the press launch, June 1963.

surplus components and constructed the first television receiver in the East Midlands to operate from the London transmitters.

Norman Rutherford went on to study, at the (then) *Nottingham and District Technical College*, and lost contact with Michael for a few years until early 1957. Then, with a 100 UK pound stake scraped up and borrowed they started a partnership and the late fifties dawned with both men making a living reconditioning television Cathode Ray Tubes (CRT's).

They started in a converted garage with Norman, Michael and one employee learning the delicate art of cutting off tube necks, removing the electron guns and rejuvenating the cathodes. New TV tubes were notoriously unreliable (usually cathode poisoning due to poor vacuum or faulty assembly) and a replacement CRT cost in excess of 20 UK pounds to purchase (equivalent to 230 pounds today). However, the Nottingham partners were bringing the price of reconditioned CRT's down to 9 pounds and 10 shillings, and in a good week could recycle well over 50 tubes through the process.

Not all CRT re-conditioning had been immediately within their grasp – Mullard tubes had removable cathodes, Mazda ones did not. But they soon solved the problem. A US company (Superior Electronics) began to sell complete electron-gun assemblies. Buying the new guns gave them an even greater edge – they had developed all the machinery and process technology (including the RF induction heating and most of the vacuum technology) for a universal CRT re-gunning process.

Now they started to make more money selling and instructing on complete re-gunning systems (proudly made by their now well established and well respected Nottingham Electronic Valve Company). The old workshops, in a disused cinema at Netherfield became hopelessly limited and the company, now with 12 employees and an accountant, moved to an old malt house at East Bridgford near Nottingham.

signal – normally (with high contrast pictures) hard to distinguish from the original 405 transmission even at lower speeds. Head fouling remained a problem with the relatively high oxide loss of early tapes, but the passive section of the head was designed to be quickly removable and cleaned.

ON THEIR OWN AGAIN

Demonstrations to Granada were unexpectedly cool, for reasons never fully explained by Bernstein. N.E.V.Co lost their sponsor at the very time it expected further investment. The reason given at the time was poor picture quality, but this was specious and clearly not the issue.

Whatever the reason, Norman Rutherford and Michael Turner had lost a major investor and somehow had to keep the business going. The Granada decision could not have come at a worse time, the tube reconditioning business had virtually collapsed with the ever-improving quality and durability of new tubes, and the company payroll was now supporting some 70 plus people. That Bernstein allowed the directors of NEV to buy back his interest for the original buying price was no consolation.

The "Combi" television/video recorder.

Initially thinking themselves fortunate, they were quick to find a new partner with the US based Cinerama corporation which had made its shareholders a massive return with the film *'How the West Was Won'*. Cinerama bought in to N.E.V.Co to the value of 200,000 UK pounds even though at this time Cinerama were, as an organization, running at a substantial loss.

WELL KITTED OUT

Time had been lost, and though not personally financially embarrassed by the new US shareholding, the two partners were aware of their financial and business vulnerability – they

Close-up shot of the TV screen during Telcan replay.

were on their own once again and looking to develop their products and product range further. Hoping to salvage the profitable divisions of the company Norman, as Managing Director, split the operation by forming Telcan (Research and Development) and Telcan TV, the latter being mainly involved in manufacturing.

Trading again in early 1963, the partners (now including a financial manager, Brian North) set out to provide the video units in kit form (as the *Telcan TKR 500*). The new operation manufactured every major component necessary including the record/replay heads, printed circuit boards, video circuits, tape transport and a variable capstan size system (0·25 HP motor). With variable speed operation (60, 120 or 180 inches per second) the kit, if correctly assembled, produced a recorder of very satisfactory performance.

A public demonstration and press conference at the Aldwich Hotel, London, held on June 24th 1963 created a wealth of interest and publicity, but the attitude of the press and the public appeared to be diffident. It was staggering that few could actually see the need for "home video recording" – even if they had the slightest notion of how technically awesome the development of Telcan was!

Norman Rutherford demonstrated Telcan on the BBC *9 O'clock News* (replaying the opening few minutes of the broadcast) but this was as ineffective as a next day ATV interview was ridiculous – the interviewer continually asking the originators if they thought Telcan a "gimmick". They were later to maintain that the interviewer could not grasp the concept of electronic recording, and mistakenly believed that the Telcan method involved the use of an 8mm movie camera (similar to a system already in use).

Orders for the Telcan units were slow. The kits sold for 60 UK pounds (some 700 pounds today) – only the technically skilled and well off could afford them. A number of pre-built units did sell well, as too did special "Combi" examples fitted into TV's, but of the total number sold the greater majority were kits.

As sales of the TKR 500 faltered, the partners designed a miniature battery driven portable record player for 7 inch 45 RPM records which, entirely self contained and enclosed, operated like a modern floppy disk drive. A fair number were produced and for a short while were popular.

ORDERS FROM OVERSEAS

However, Cinerama, already a stockholder in N.E.V.Co, proposed through its Chairman Nicholas Riesini, the formation of a joint company for exploitation of Telcan in the US and, given the other possible financial holdings of stock in N.E.V.Co, agreed to purchase any stock willing to be released by other interests. This ultimately resulted in a fairly large injection of new cash for the company and R&D was the first to benefit. For a moment there appeared to be yet another new beginning for the company.

Unfortunately, what was desirable in one context was not in another, and the two partners found themselves embroiled in business negotiations and legal entanglements to the detriment of the company's main business. In December of 1963 Norman and Michael were asked to demonstrate the video recorder at a crucial shareholders meeting of the ailing Cinerama Corporation at the Capital Theatre, Broadway in New York.

However, they were asked to try something novel – to video the shareholders themselves at the meeting. Being away from base, and unable to get one of their own *Mini-Eye* 4 inch cameras, Norman got hold of a 525-line studio standard Vidicon camera and videoed all and sundry, amazing everyone by playing back the pictures at the meeting.

The technology was enough to placate all of the unhappy shareholders – now absolutely convinced that Cinerama had a real winner. However, all was not sweetness and light, Cinerama itself was not actually able to invest any further – even though its individual principals were well able to. The partners returned from the US with the mistaken expectation of a large order for the new *"Telcan"* system but it failed to materialize.

As Cinerama floundered the Chairmanship changed to that of William Foreman, a creditor of Cinerama. Foreman was not slow to convey his personal distrust of the Telcan business to the new Executive.

The Wesgrove (Telcan) kit of components (1963).

Acknowledgements.
The author offers his sincere thanks to Mr. Norman Rutherford (for patiently retelling his story for the umpteenth time), to Mr. Rob Cox, curator of the Wollaton Hall Industrial Museum in Nottingham, Mr. John Brunton at the Nottingham Post, and to all those that gave their time to find, or process, material for this article.

One of the last remaining examples of the Telcan video recorders on show at the Wollaton Hall Industrial Museum, Nottingham, UK.

Sensing mounting hostility from their new principals, the two partners decided to look further afield for investment and gave demonstrations in the US to the Filco (Ford Motor Co.) and Admiral Corporations. But the interest and enthusiasm was less than it might have been in the face of an ever-growing hostility and starvation of funds.

In hindsight, Norman Rutherford admits that had they "toadied" a little to their new partners things may have gone better. In short, there was only one way out and in August of 1964 Norman Rutherford, as Managing Director, put the company into voluntary liquidation.

OVERSTRETCHED

Undaunted, and with the greater number of their 70 odd original staff still at hand, the two partners set up again at Basford under the name Wesgrove. Again this was a kit form recorder business though, as always, customers could purchase a fully assembled version.

Unfortunately, by this time, the Ampex helical scan system had already appeared in competing domestic video recorders. One leader was the Sony 0·5-inch reel-to-reel video recorder; Philips were also competing while a further system was marketed by Loewe Opta in Germany.

The message was obvious, the Telcan linear system needed to be updated to record in the helical scan mode in order to rival other products. But this was beyond the resource of the already ailing and overstretched Telcan-Wesgrove operation. Talks with various potential backers, even Japanese interests, got nowhere. The Wesgrove business, like its predecessor, was put into voluntary liquidation just 19 months after the Cinerama debacle.

EPILOGUE

Only two of the original Telcan units built by Norman Rutherford and his Company survive to this day – one in San Francisco, owned by Al Cox the owner of a music shop and FM radio station, and one now to be seen at the *Wollaton Hall Industrial Museum* in Nottingham. Norman and his partner Michael Turner became disaffected and parted company just after the firm was wound up.

Norman continued to do some consultancy work in electronics; he eventually gave up and went into property development with his brother, only returning to his first love in the early 1980's when he became involved in developing an infrared transmission system for closed circuit TV. He finally found lasting fame by way of an entry into the *Guinness Book of Records* in 1982.

Much could be said about this lost opportunity for British enterprise in terms of too little too late, but the reality is

different. The technical principle was only good enough to prove the value of the product – for all the negativity faced at the Telcan launch, everyone quickly came to see how useful a home video unit could be and that a massive market awaited.

Although the original technical principle of Telcan defined the operational limits, the linear record system was never going to have the technical flexibility required by the market (for convenient long play, high resolution monochrome or color recording). Also, the short record / replay time, and poor long-term head dependability were very much a weakness.

Yet, for all that the promise was there, and had the investment vision come anywhere close to the technical vision, then a good deal more might have been accomplished.

As it was, the two partners, Norman Rutherford, Michael Turner and their associates did unequivocally demonstrate and sell the first commercial *home* video recorder, the first Camcorder (and the first "Combi" TV and video recorder). What price "vision"?

Go to next section

WATERMARKING MUSIC

Barry Fox reports on the arrival of a new method to prevent unauthorized music copying.

The music and electronics industries have agreed on the technology they will use to bury a watermark in music recordings to control unauthorized copying from the Internet. The Secure Digital Music Initiative, a committee of 120 hardware and software companies, has chosen MusiCode from Aris Technologies of Cambridge, Massachussetts, USA.

The SDMI was formed when record industry trade body the Recording Industry Association of America failed in its legal bid to block sales of Diamond Multimedia's Rio, the pager-sized solid state recorder that uses MP3 compression technology to download and replay music from the Internet.

WATERMARKED SOURCE

SDMI agreed that music will be watermarked at the recording studio with digital code which identifies the copyright owner and tells how the music is intended to be sold, for instance on a CD. An "SDMI-compliant" Internet music player will search for any watermark, which reveals that a recording is an unauthorized copy from the Internet, and refuse to play it. Laws will be tightened to stop people modifying players so that they ignore "don't play me" marks.

The SDMI wanted a mark that can survive to-and-fro conversion between the analog and digital domains and resist hackers who try and wash it out, while not degrading the sound. 4C Entity, a consortium of IBM, Intel, Matsushita (Panasonic) and Toshiba, took on the job of testing 11 different proposals.

Some spread a thin layer of modulated noise under the audio; others suck notches from the music and add modulated noise to the gaps. MusiCode works in a completely different way.

CODED SYMBOLS

The encoder in the recording studio holds a library of symbols, digitally coded letters of the alphabet and numbers, which are represented by predetermined patterns of a musical waveform. These can be peaks within a limited range of heights, which occur within a fixed period of time. The encoder analyses the music, looking for patterns that are similar to the library patterns. When a close match is found for a symbol that is to be buried in the music, the encoder modifies the music peaks so that they exactly match the library symbol.

A decoder in the player holds a library of symbol representations like those in the encoder. When it finds a matching pattern in the music it triggers the appropriate symbol. Together the symbols build up a copyright message.

The symbol data rate varies depending on the music content, but is typically around 100 bits per second. So it takes a few seconds for the decoder to recognize all the symbols needed for a copyright message or copy-control signal.

GOLDEN EAR TESTS

Aris claims that although the music waveform is slightly altered to convey the symbols, there is no noticeable effect on the sound, even when it comes from a super hi-fi source such as a DVD-Audio player, with frequency range of 100kHz and dynamic volume range of 140dB.

Audio enthusiasts have always been wary of anything that alters the sound but Aris says the tests done by 4C prove the system works. 4C built on the so-called Muse tests of CD watermarking which were carried out in Europe with EU funding by the music industry's trade body the International Federation of the Phonographic Industry. All the major record companies played music in their studios to panels of "golden ear" audio experts listening to marked and unmarked music without knowing which was which.

Paul Jessop, the IFPI's Technical Director, organised the European tests has confidence in the SDMI's findings.

"I am delighted" he says *"that we have found a technology that independent listening tests have shown to be inaudible".*

SCEPTICISM MAY REMAIN

The SDMI, like the IFPI, refuses to name any of the *"internationally recognized golden ears,"* which it claims were satisfied. Paul Jessop says he knows what this means. Audio enthusiasts will refuse to believe that any mark can be inaudible and be sure they can hear degradation even when there is none.

Renowned US mastering and recording engineer Bob Ludwig had previously warned that although watermarking might be inaudible on lo-fi Internet music, its effect on super hi-fi DVD-Audio would be noticeable. He said he was wary of any reassurances from the RIAA, which had argued in the 1980s that the Copycode notch system was inaudible.

Ludwig now says *"my fervent hope is that digital signal processing has improved to the point where watermarking can be totally inaudible under all reasonable circumstances".*

LIFE, THE UNIVERSE, AND THE UK

The British National Space Center has announced that the search in the UK for life in the Universe is on! Astrobiology – a new science to search for life across the Universe – was launched in mid-December '99 and the excellence of UK scientists puts us in a strong world position.

Dr Don Cowan, Chair of the panel of experts that spent last year investigating work currently underway in the UK, recently made the following statement:

"This is a really exciting time in Astrobiology. In our investigation we found many British scientists who were Astrobiologists without knowing it; biologists were studying how life survives in the harsh environment of Antarctica, astronomers were developing new missions to find new planets, chemists were developing new techniques to identify biochemical markers, geologists were studying the way life transforms the properties of our planet. Brought together they make a powerful force in Astrobiology which will enable us to find out still more about where we come from and what other life might exist or have existed in the universe."

In a separate statement, Science Minister Lord Sainsbury has announced that the UK is to invest 1.4 million UK pounds in the experimental and research opportunities offered by the European Space Agency's EMIR-2 program. The funding includes 15 million pounds investment in the UK small satellite sector, helping transfer the UK's world-leading capability in small satellites from the academic into scientific and commercial markets.

Furthermore, Surrey Space Center, run by the University of Surrey at Guildford, tell us that NASA has once again selected Surrey Satellite Technology Ltd (SSTL) as the only non-US supplier for its Rapid Spacecraft Acquisition contracts over the next five years.

Under the contract, SSTL will supply its flight-proven off-the-shelf mini-satellite platform for space and science technology missions to all of NASA's centers and other US Government agencies.

SSTL's first mini-satellite, UoSAT-12 was launched in early '99 and their sixteenth, Clementine, was launched in December '99.

All-in-all it seems an excellent start to the new millennium for the UK's involvement with Space. Surf **www.sstl.co.uk**

Guiding Inventors

A step-by-step guide to help inventors make an informed choice about using invention promotion companies has recently been published on the Internet by Lord Sainsbury, DTI (Department of Trade and Industry) Minister with responsibility for science and innovation. The guide is intended to help inventors get the most out of promotion services and provides advice on finding sources of free or low cost information.

Said Lord Sainsbury, *"I do not want creative individuals to become unsuspecting victims of unscrupulous firms. I am confident that the easy-to-follow steps will help inventors avoid making costly mistakes".*

The DTI factsheet can be accessed at **www.innovation.gov.uk.** Another useful Web address is that of the Patent Office, at **www.patent.gov.uk.** The DTI's phone number is +44 (0) 171-215-5000.

QX3 INTELPLAY MICROSCOPE

Matel, the world's best-known toy maker responsible for favorites such as the Barbie doll, has teamed up with Intel to produce a range of toys to complement the personal computer. Aimed at the six year-plus market, the marvelous Intelplay QX3 microscope is a Universal Serial Bus (USB) compatible device that allows color images to be captured on a Pentium PC at several magnification factors, from x10 to x200. This allows youngsters to explore the fascinating world of microscopy and see images live on-screen.

Magnification factors refer approximately to the size of the image when viewed on a 15-inch computer monitor, say Mattel: this would, for example, enable a 1mm mustard seed to become a wonderful 20cm knobbly spheroid on a 19in monitor. The microscope resolution is 512 x 384 pixels, which is more than adequate for most investigations.

The excellent Windows software, replete with brilliant and fun sound effects, permits live viewing of the object (the frame delay depends on the throughput performance of the PC – it can appear virtually real-time on a 350MHz desktop). Still-capture and time-lapse movies can also be produced, perhaps to illustrate the growth of a mung bean or the movement of star-struck creepy crawlies. Slide-shows of microscopic montages, accompanied by some great sound tracks, can easily be put together by budding young boffins. Images can be printed or exported as bitmaps, and there is a great paint package included which allows pictures to be suitably enhanced.

The microscope has colorful chunky controls to allow youngsters to control the magnification and focus, and a push-button allows still images to be captured on disk for future reference. The QX3 incorporates two filament light sources (above or backlit) which are selectable through the software. The microscope unit can be detached from its stand to allow free-standing use, and the USB lead is approximately three meters long for this purpose.

It is completely powered through the USB connection and requires no extra mains adaptor or batteries. This also means that it could be used as a stand-alone device with a USB-enabled laptop computer, perhaps for junior field studies.

A complete kit is supplied by Mattel, including an Activity Book, sample slides and containment capsules. Everything is safely molded in plastic of a high quality, with no glass parts or sharp edges being present. Although it was launched towards the end of 1999 in the USA, our reviewer managed to obtain one of the first in Europe earlier this year, and had great fun exploring various natural objects, such as seeds, shrimps, sugar crystals and the anatomy of honey bees. Surface-mount electronic devices found their way under the lens too, and some reasonable photos captured of SMD chips and close-ups of soldering.

The QX3 is a fantastically creative educational gadget – much more than a toy – and is bound to be a big success with children, parents and teachers. Expect a UK launch in late Summer 2000, at a price of approximately 90 UK pounds.

Alan Winstanley

EMF Facts

There has been a lot of publicity for the topic of EMF (electromagnetic fields), much of it having a negatively-biased approach. We have been advised that the new Safety Test Solutions web site, **www.safety-test-solutions.de**, offers a wide range of information on this topic. It tells you about the characteristics of EMF, where they occur and their effects. It also explains technical terms.

The website information is available in English, French, German and Spanish, on a wide variety of subject areas. *"On our new website, every visitor will quickly find the information they need, no matter whether they are getting involved with electromagnetic fields for the first time, or if they are an EMF expert looking for detailed information",* stated Hans J. Forster, Executive Director of Safety Test Solutions.

TITANIC RECEIVER DISCOVERED

A unique and valuable Edwardian crystal receiver, made in England in 1910, has recently been unearthed by a Midlands antique dealer, and has been acquired for a major private wireless collection in this country.

Early radios of this period are rare enough, but what makes this particular set especially unique is that its maker, Mr George Leadbetter (a machine turner and clock repairer then living in Ledbury, Worcestershire), while listening-in on the set's earphone on the morning of Monday 15th April 1912, suddenly tuned into the sinking *Titanic's* CQD/SOS Morse distress signals.

Unfortunately, having run round to the local police station to tell the sergeant what he had heard, he was turned away, none of the police officers on duty believing what he had to say!

It would be difficult to know what help Mr Leadbetter"s news could have been had he been believed (the *Titanic* was some 3,000 miles away across the other side of the Atlantic), but help was nearby and the distress signals were picked up by ships close at hand, resulting in the rescue of over 700 passengers and crew.

Such a pivotal role did wireless play in saving many hundreds of lives on board the stricken ship that its value was dramatically demonstrated and acknowledged around the world.

This beautiful engineer-made radio, measuring some 24in x 14in x 9in (60cm x 35mm x 7cm) and weighing 42lb (18kgs), is the only surviving radio receiver documented as having heard the distress cries from the *Titanic* – a fantastic relic from this most famous of historic disasters. A photo of the receiver is shown in this month's *Technology Timelines* feature.

The receiver will be on show in pride of place at the next *National Vintage Communications Fair,* which will be held at the NEC in Birmingham on Sunday 30th April 2000.

Other exhibition items on show at the fair will be a comprehensive collection of WWII spy radio transmitters and receivers, a Horophone time-signal receiver (another unique Edwardian radio), and a display depicting the history of recorded sound.

For more information contact The National Vintage Communications Fair, Spice House, 13 Belmont Road, Exeter, Devon EX1 2HF, UK.

Tel: + 44 (0) 1392-411565

Email: sunpress@eurobell.co.uk

Web: www.angelfire.com/tx/sunpress/index.html

(If you are interested in vintage radio, why not take out a subscription to our sister magazine, *Radio Bygones*? For details see **www.radiobygones.com**)

Go to next section

Shop Talk

with DAVID BARRINGTON

Some Component Suppliers for EPE Online Constructional Articles

Antex
Web: **www.antex.co.uk**

Bull Electrical (UK)
Tel: +44 (0) 1273-203500
Email: **sales@bull-electrical.com**
Web: **www.bullnet.co.uk**

CPC Preston (UK)
Tel: +44 (0) 1772-654455

EPE Online Store and Library
Web: **www.epemag.com**

Electromail (UK)
Tel: +44 (0) 1536-204555

ESR (UK)
Tel: +44 (0) 191-2514363
Fax: +44 (0) 191-2522296
Email: **sales@esr.co.uk**
Web: **www.esr.co.uk**

Farnell (UK)
Tel: +44 (0) 113-263-6311
Web: **www.farnell.com**

Gothic Crellon (UK)
Tel: +44 (0) 1743-788878

Greenweld (UK)
Fax: +44 (0) 1992-613020
Email: **greenweld@aol.com**
Web: **www.greenweld.co.uk**

Maplin (UK)
Web: **www.maplin.co.uk**

Magenta Electronics (UK)
Tel: +44 (0) 1283-565435
Email: **sales@magenta2000.co.uk**
Web: **www.magenta2000.co.uk**

Microchip
Web: **www.microchip.com**

Rapid Electronics (UK)
Tel: +44 (0) 1206-751166

RF Solutions (UK)
Tel: +44 (0) 1273-488880
Web: **www.rfsolution.co.uk**

RS (Radio Spares) (UK)
Web: **www.rswww.com**

Speak & Co. Ltd.
Tel: +44 (0) 1873-811281

Micro-PICscope

For those readers who like the look of the neat orange plastic box used in the *Micro-PICscope* project, this is an RS product and can be purchased through their mail order outlet Electromail (code 281-681). They can also supply the MAX492 dual opamp (code 182,2738).

The 2-line 16-character alphanumeric liquid crystal display module, complete with connector, used in the prototype was originally purchased from Magenta Electronics and we understand that they still have stocks of this device.

The PIC16F876-20P used in this project is the 20MHz version. For those readers unable to program their own PICs, a ready-programmed 16F876 can be purchased from Magenta (see above) for the inclusive price of 10 UK pounds (overseas readers add 1 UK pound for postage). Software for the Micro-PICscope (written in TASM) is also available for free download from the *EPE Online Library* at **www.epemag.com**

The printed circuit board is available from the EPE Online Store (code 7000259) at **www.epemag.com**. Finally, data sheets for the PIC16F87x family (and other PIC products) are available for free download from Microchip's web site: **www.microchip.com**. Maxim manufacture the MAX492 opamp used in this design. Their web site is at: **www.maxim-ic.com**

Garage Link

The main items of concern regarding the *Garage Link* project are likely to be the transmitter and receiver modules and the Holtek encoder and decoder chips.

Starting with the HT12E encoder and HT12F decoder, the last time we looked for similar Holtek chips they were in very short supply and FML Electronics (Tel: +44 (0) 1677-425840) bought some in. Once again, we understand they are happy to supply the above encoder and decoder ICs.

Regarding the RF Solutions AM transmitter and receiver modules, several component suppliers, such as Suma Designs (Tel: +44 (0) 1827-714476), Quasar Electronics (Tel: +44 (0) 1279-306504), and Veronica Kits (Tel: +44 (0) 1274-883434) may be able to help. Also, Maplin are currently listing a low cost pair, quote code VY47B.

The last mentioned company also supplied the lever-arm microswitch (code NF21X) and the miniature LDR (code AZ83E). You can, if you wish, use the good old ORP12. The 66MΩ resistor for R5 in the Transmitter was made up from two 33MΩ "high voltage" types (code V33M). The two printed

circuit boards come as a pair and are available from the *EPE Online Store* (codes 7000261 – transmitter, and 7000262 – receiver) at **www.epemag.com**

Flash Slave

Not much can go wrong when shopping for parts for the *Flash Slave*, this month's simple *Starter Project*. The phototransistor may cause some local sourcing concerns, but, as the author states in the article, several *npn* types have been successfully used in the unit. The BPX25 *npn* phototransistor used in the prototype came from Maplin (code QF30H).

We understand that some overseas readers are having difficulty finding ZTX type transistors locally, so we suggest they opt for the 2N3440 type. Other, high voltage and high current transistors should work equally well in this design. One important point though, like the 2N version, the pinout and encapsulation may differ and must be carefully checked before inserting on the circuit board.

High Performance Regenerative Receiver

As we highlighted last month, some of the type numbers quoted for the "plug-in" TOKO coils called for in the *High Performance Regenerative Receiver* did not tally with our information. However, thanks to efforts on the part od the designer – Raymond Haig – the TOKO coil numbers and ranges used in the Receiver have been set out in Table 2 in the article and were purchased from Bonex Ltd (Tel: +44 (0) 1753-549502), type numbers and order codes are as follows: CAN1A350EK, 380-350; RWO6A7752EK, 3357-752; RWR331208NO, 351-208; 154FN8A6438EK, 356-438; KANK3426R, 363-426; KANK3337R, 363-337; MKXNAK3428R, 363-767. We have also been informed that JAB Electronic Components (Tel: +44 (0) 121-682-7045) stock an extensive range of TOKO coils.

One item we neglected last month was the slow-motion reduction ball-drive for the tuning capacitor. Glancing through a "flyer" from Mainline Surplus Sales (Tel: +44 (0) 870-241-0810) we see they list one for just 2.50 UK Pounds, plus a 3 pound (UK) post and packing charge. Quote order code 81-0224.

The three small printed circuit boards are available as a set from the *EPE Online Store* (codes 7000254, 7000255, and 7000256) at **www.epemag.com**

Teach-In 2000

No additional components are called for in this month's installment of the *Teach-In 2000* series. For details of special packs readers should contact:

ESR Electronic Components – Hardware/Tools and Components Pack.

Magenta Electronics – Multimeter and components, Kit 879.

FML Electronics (Tel: +44 (0) 1677-425840) – Basic component sets.

N. R. Bardwell (Tel: +44 (0) 114 255-2886) – Digital Multimeter special offer.

PLEASE TAKE NOTE: *Video Cleaner Feb '00*

Amended software is now available via the EPE Online Library at **www.epemag.com**. The INIT routine should read:

```
INIT CLRF    PORTA
     BSF     STATUS,
PAGE1
     MOVLW   B'00000000'
```

This configures PORTA as outputs only.

Go to next section

Readout

***John Becker** addresses some of the general points readers have raised. Have you anything interesting to say? Email us at editor@epemag.com!*

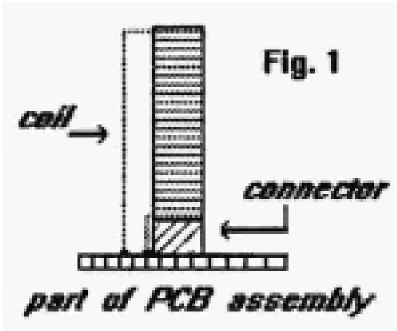
FUSED COIL FORMERS

Dear EPE,

Reading much of the series recently on *Practical Oscillator Design* (Jul-Dec '99), has prompted me to come up with a practical idea for constructors of RF oscillators etc.

Basically the idea, which I have already put into practice, makes use of the ordinary household 3A/13A ceramic fuse. Prepare to dismantle the fuse by easing off one end with pliers, whilst the other end is secured by soldering it to a piece of scrap PCB for support. Discard the internal fuse wire plus sand, and a very nice ceramic coil former remains, also keep the connector at one end, this will prove useful too.

Ceramic type coil formers are often referred to in the ARRL Handbook in numerous construction articles for VFOs etc, and apart from the excellent mechanical and temperature stability they offer, coils can easily be wound



and secured using the following method:

By soldering the lower contact of the fuse to a small pad on the etched oscillator PCB, the coil can be wound as in Fig.1, and the turns held tightly, whilst the "hot end" of the coil is soldered to its intended point of the circuit, before any other components are mounted. By applying a smear of Araldite to the coil layers, and holding a 25W iron near, heat and melt the resin whilst turning the former, this will ensure a uniform, covering and ultimately hold the turns permanently in place.

In fact, many of your readers will probably be familiar with heating of Araldite to increase its flow and quicken its setting time, and in this application the coil will appear glazed, as if encased in glass!

Using 28 or 30swg enameled copper wire and using most of the length of the former, popular MF frequencies and beyond can be covered with the appropriate value of capacitor.

Hopefully readers can be encouraged to experiment using items such as fuses to provide potentially excellent coil formers, rather than the seemingly ever elusive pre-wound coils – once found in constructors' catalogues. In fact the humble fuse can also be used as PCB stand-offs!

D.B. Venuti
Thurgarton, Norwich, UK

A very useful suggestion, and one which we are pleased to publicize. Thank you DB – enjoy your new meter!

PC SCREEN DUMPS

Dear EPE,

I commend John Becker and your team on your intuitive treatment and presentation of electronics in the *Teach-In 2000* series. The accompanying interactive computer program is also very impressive.

It looks as if the printed screen-shots are actual photographs of a PC monitor taken with a camera. Indeed, this seems to be your method for reproducing any PC graphical output. You probably have your own reasons, but just in case, I have a suggestion that would save time and effort, while also dramatically improving the quality of the reproductions. The following applies to IBM-compatible PCs only, running Windows 3.1, 95, 98 or NT.

Pressing the <PRINT SCREEN> button (located beside the <SCROLL LOCK> key) on the keyboard causes the monitor output at that time to be stored to the clipboard. The "Edit Paste" command, available

in most Windows-based editing software, can then be used to dump the image into a document, or in the case of a graphics editing package, into an image file.

To capture DOS output, run the DOS-based program from Windows at the full screen setting, hit <PRINT SCREEN> to capture the desired output and use the <ALT> <TAB> key combination to return to the Windows editing program for subsequent pasting. It is then also very easy to label the image with graphics editing software if desired.

Active Dialog/Message boxes can be neatly captured to the clipboard by pressing <ALT> <PRINT SCREEN>. This causes the background graphics to be omitted from the capture.

I thoroughly enjoy your magazine, and with practical circuits, it certainly lives up to its name.

John Harris
Co. Longford
Ireland

Your assumption about using screen photos is absolutely correct. I did not know that my computers were capable of screen saving in this way from a DOS-based program. Other authors have previously provided us with electronically captured images, but I had assumed they had special software.

I tried it when I saw your e-mail and it worked nicely, enabling the images to be stored to disk and passed to our in-house typesetting team. The screen images in this month's Teach-In *have been done this way. Thank you.*

Your e-mail was actually passed to us by Max, our Online edition editor in the USA. He added the following additional advice:

If you want to see how easy it is in normal Windows mode, just press (and release) the Print Screen *button now, then use* Start > Programs > Accessories > Paint *to open the simplest of paint programs and then use* Edit > Paste *and see what happens – you can then save this image as a .BMP file, and then use Adobe Photoshop to shrink it and/or change it into other formats.*

It's also worth noting that pressing the Print Screen *button on it's own captures the entire screen, while pressing and holding the <Alt> key and then pressing the* Print Screen *button will only capture whichever window is currently active. Cheers – Max*

UP TO SCRATCH

Dear EPE,

EPE Jan 2000 – best issue for a long time, as well as being PIC-free! Glad I renewed my subscription.

The mag arrived as I was finishing writing up notes and drawing the circuit diagram for something I've just finished and I was trying to remember the symbol for a thermistor (not something you use everyday), so I was well pleased with Fig.3.3 on page 33. I really think the *Teach-Ins* are one of the best things you do. I have been a hobbyist on and off for nearly 50 years since I built a one-valve set, later converted to mains for the HT, given the price of 90V HT batteries, and my first serious electric shock (no namby-pamby PP3 batteries then!). I have found there is always something new to learn. In fact the reason I read *EPE* today is down to picking up the Jan '93 issue in WH Smiths, glancing through *Teach-In 93* Part 3 and that is why I subscribe!

Regarding "Notations" on page 32 (Jan '00), I have used quite a few pots made by Radiohm that are labeled, for example, 10KA, 10KB or 10KC where A, B and C indicate lin, log, and reverse-log respectively. I always assumed that this was a house code, but I have seen it used on published circuit diagrams too. Also, an Omeg pot I have is labeled 10K LIN.A. By the way, if you take two dual-gang Radiohm or Omeg pots and disassemble them, you can rebuild them as one 3-gang and a single-gang pot (nothing wasted!). The 3-gang pot makes a passable 18dB/octave variable Sallen and Key filter a possibility. I have assembled a 4-gang pot but it's no good trying for a 24dB/octave filter as the matching is not good enough.

Robert Penfold's *Practically Speaking* feature on page 58 demonstrates how difficult it is to insulate transformers of the style illustrated in Fig.2 since the center tap is not insulated nor are the vertical parts of the tags where the ends of the windings are soldered to. If possible, I usually try to mount a transformer so that the primary tags are difficult to touch and have often thought this would be easier if the primary tags were at the bottom of a transformer and not the top. Where this is impossible I have either stuck a piece of acrylic sheet on top of it with double-sided sticky foam pads or fashioned a shroud from "Masticard" as used by model makers. I cannot think of any better way and it does seem daft that you can buy a boot for the mains inlet but have to improvise on the transformer.

I also studied Robert's *Scratch Blanker* (Jan '00) very carefully as I am about to build a similar device using a Reticon SAD1024 CCD delay line that I bought years ago for the purpose and never got round to. I had dug out my old notes and cuttings. One of the cuttings was *An Experimental Scratch Eliminator* (*Hi-Fi News* Sept-Oct '79) by one R.A. Penfold, which makes me wonder if it is coincidence that 20 years later when I am about to build what I started thinking about in 1979, Robert Penfold publishes another design. Spooky!

Barry Taylor
via the Net

Thank you Barry for another interesting contribution to Readout. Sorry we can't publish it in its entirety.

TEACH-IN 2000 HELP!

Dear EPE,

Thanks for the wonderful magazine. I had been trying to get involved with electronics for a while, but our local library did not have enough info. Then I found out about *EPE*. I began reading the magazine in Aug '99, understanding little and eventually subscribed to *EPE Online*. The *Teach-In 2000* series has really helped me to begin understanding electronics.

I was working on the experimental section of Part 4 and found that on my computer the readings I get for the 8-bit data output are -5V for low and 0V for high. The same with the inputs. I reversed the polarity of my input voltage to get the programs to work. I hope this will not affect the programs in any way and that I will be able to continue with the wonderful Tutorials.

The computer was purchased as is, second-hand and has a Pentium 166MHz processor, that's about all I can tell you about it. I also used a length of 25-way ribbon cable with a male 25-way D-type snap-in adapter on one end and soldering the ends of the cable to strip board on the other end. I did this so I don't need to make a PCB for the Centronics adaptor.

Hitesh Lala
South Africa

Great to know you appreciate us! The only reason I can think of for the negative values is that you are connecting the meter in back-to-front. The COM lead should go to 0V, i.e. the negative terminal of your battery, or the metal chassis or other known ground (0V) point of your computer or its connecting lead.

The Centronics parallel connector to the breadboard for Teach-In *has more than just one pin that can be used for ground (0V) connection. Pins 19 to 29 provide separate grounds for the screening on individual signal wires, pin 16 is Logical ground, pin 17 is Chassis ground, while pins 30 and 33 are quoted in my source book as just being Ground.*

Look closely at the connector for the identity of the pins. Note that once you have found pin 1, the numbers follow sequentially to the end of that row, and continue on the second row from the pin immediately opposite pin 1. This is contrary to the order in which DIL IC pins are numbered, going down one side and then back up the next. This explains the cause of the pin numbering error in Fig.4.6 (Feb), as reported last month (March); the author (me!) had erroneously counted in the wrong direction – how infantile!

TEACH-IN AND PSION (2)

Dear EPE,

As a person who is involved mainly in Computers/IT, and only dabbles in Electronics as a very part-time hobby, I feel relatively refreshed to be able to answer one of the questions posed in your *Readout* section.

I refer to the letter from *Federica Appolloni* in the January 2000 Issue of *EPE Online*. Federica is trying to use the *Teach-In 2000* software on an XT-Emulator.

Normally, I don't think that there would be a significant problem in using the software on a Real XT based PC. I think that the problem is caused by the display mode used by the software. The display resolution required by the *Teach-In 2000* software is just not possible on a Psion series 5 palmtop. The error generated would be consistent with an attempt to switch to a different display mode failing.

Mike Insch
via the Net

Thank you Mike. The resolution of the screen mode used (Screen 9 in QBasic/QuickBASIC, EGA/VGA) is 640 x 350 pixels, with text set for 80 characters x 25 lines, 16 color attributes.

Interestingly, with regard to the "hieroglyphs" problem being experienced by some readers (see several previous Readouts*), I have succeeded in simulating the situation (via codepage commands) on two of my machines and found that problem then exists with text set for 80 x 25, but not with it set for 80 x 43*.

DOING IT RIGHT!

Dear EPE,

I bought a copy of your magazine the other day after a nine year gap. I was pleasantly surprised to find that the comfortable old format was pretty much intact, and that the regular contributors like Robert Penfold were still hard at it, doing their best to instil their wisdom to us readers, and even the familiar old Bull Electrical ad. inside the front cover was still there after all this time. The small details such as the component lists and the stripboard layouts, and even the little cartoon illustrations brought the memories back as if I'd only bought a copy last month.

The noticeable changes included things like the Internet feature *Net Work* and the fact that most advertisers now have web sites (which is good news), and that everyone seems to be going on about this PIC processor thingy (sorry to be an ignoramus). But it was reassuring to know that some institutions like *EPE* have remained essentially unchanged over nearly a decade, even despite a merger with another publication (when I was a regular reader in '91 it was of course *Everyday Electronics* I read).

Some might say that this shows a lack of progress on the part of the publication, but I say that in reality what it means is that the formula is right and therefore doesn't need to change.

My life veered away from electronics in '91, but now after the re-igniting of my interest in hobby electronics thanks to another interest of mine, cycling, and the desire to build a two-stage sealed lead acid battery charger to charge my self-designed front lighting rig, I am glad I did pick up a copy of *EPE*, as I found it as enjoyable to read now as I did back then.

I also found/find *EPE* a valuable source of suppliers of parts thanks to the ads, but I noticed that your Online issue (judging by the sample issue only) does not contain these ads. I see the adverts as almost as an important part of the magazine as the articles, and thus it seems a shame to omit them from the electronic version, especially when so many have web presence these days that overseas subscribers can also contact them very easily. Just a thought.

Please keep up the good work and the high quality of *EPE* and be assured that your publication is probably amongst a very small minority that seems to have got it right.

Jason Webb
Reading, Berks

Thanks for your kind comments, Jason. Some may regard us as a bit staid, but as you said, it seems to work OK. We are moving towards ads in the Online version. Watch that space!

TEACH-IN BUG

Dear EPE,

While using the TY2K (*Teach-In 2000*) software I have stumbled on a bug with the self-test of the *Resistor Values and Color Codes* program. The first four questions ask for the resistance to be typed in, and this is followed by four questions which ask for the resistance to be selected graphically.

When the last of these questions is answered correctly (eight questions), the program gets into a loop where the question remains unchanged and the graphical value of the resistance changes to what the program thinks should be the correct next answer. Typing <Enter> several times just gives the correct answer. After pressing <A> to get the answer, the program gets back to normal, only to repeat the same after the 16th question, and so on.

Thanks for a great *Teach-In* series and for a great magazine.

Federica Appolloni
via the Net

So it did! I've now fixed it and the fix will be released when software version V1.1 (with more demo routines) is released with Teach-In 2000 Part 7. *In the meantime, just remember that this bug is lurking (but it's not malignant and it's not a Y2K bug – has anyone encountered one of those yet? I haven't)*

.

SOLDERING TIP

Dear EPE,

I have a question on soldering iron tips. After a job is done I have been told to put a small amount of solder on the tip and then unplug the soldering iron. I have also been told do not do it. Who is right?

Michael Powell
via the Net

On-line Editor Alan Winstanley received Michael's query, and replies to it:

I always dab a small amount of solder on the tip to tin it, wipe it clean on a damp sponge and then unplug the iron and let it cool while the tip is still nice and shiny. This preserves the cleanliness of the tip ready for the next job. However, you MUST WIPE it clean before unplugging, or the excess solder and flux will just burn and "dull" the tip and lead to unwanted deposits before the iron has gone

cold.

If you don't use the iron for a time (say 5 to 10 minutes or more) before switching off, the tip is bound to be dirty when it cools down due to baked-on flux deposits, oxides etc. This could make it harder to clean up the tip when you next switch it on. (Brand new tips can gradually be made unusable for this reason. Hence you must always thoroughly tin a new tip straight away.)

If a tip is always kept nice and shiny, it is always easier to use. It will accept solder readily and let you solder accurately and more quickly. So whoever told you to add some solder is right – provided you wipe the tip to remove any excess solder, before the iron has gone cold.

(Also, don't forget that Alan Winstanley's Soldering Guide featuring lots of cool photographs is available in the EPE Online Library at **www.epemag.com***).*

SERIAL LOG

Dear EPE,

I'm designing and building an automatic weather station based around the PIC16F877. I've been pinching ideas and bits of circuit from your *PIC Data Logger* (Aug '99) and *PIC Altimeter* (Sep '98).

I've been trying to get a serial RS232 link from the PIC's USART to my PC working (to transfer results). I used exactly the circuit and cable pinout you have in the *Data Logger* except that, not finding a spare 7404 buffer in the components box, I used a couple of NAND gates with paralleled inputs from a 4011 instead. I eventually succeeded in getting it going, but only by using one of the gates, not two in sequence as in the *Data Logger* circuit. In other words I had to invert the output from the PIC's RC6 pin.

I checked with Microchip technical support about this. The RC6 output is indeed inverted, and is intended to be used with an RS232 transceiver, most of which invert the input signal (so that on the line side of the transceiver chip the output is correct).

Since your design puts the signal through two inverting buffers in sequence, i.e. retains the inverted signal as output by the PIC, how did you ever get it to work at all? I looked through your PC comms input program (DATLOG02.BAS), but I couldn't see anything that was doing anything strange to the hardware – but I don't use QuickBASIC so I'm not an expert in it.

But if you get any queries from folks with older kits who can't get it to work, you might suggest that they try using something like the MAX232CPE instead of the 74HC04. R.A. Penfold had a useful article on using this chip (*Interface* July '96).

Malcolm Wiles
via the Net

As I explained in the Data Logger *article, and advised to Malcolm, I am not an expert in comms port use and had to research heavily before achieving a working circuit, which was subsequently proved on my several computers.*

What Malcolm missed when examining the .BAS code is that a machine code routine is also accessed, this doing the actual reading of the comms port. In it the data is indeed re-inverted. The full machine code text can be read in file DATLOG02.J.

Go to next section